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INFORMATION CIRCULAR

MULTIPLE-SHIFT MECHANICAL MINING IN SOME BITUMINOUS-COAL MINES

PROGRESS REPORT 4. EXTRACTION OF PILLARS WITH MECHANIZED EQUIPMENT

BY

ALBERT L. TOENGES, EARL R. MAIZE, AND FRANK A. JONES

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

MULTIPLE-SHIFT MECHANICAL MINING IN SOME BITUMINOUS-COAL MINES

Progress Report 4. Extraction of Pillars With Mechanized Equipment[1]

By Albert L. Toenges[2], Earl R. Maize[3], and Frank A. Jones[4]

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2/ Principal coal-mining engineer, Fuel and Explosives Service, Bureau of Mines.

3/ Senior coal-mine inspector, Coal-Mine Inspection Division, Bureau of Mines.

4/ Assistant mining engineer, Coal Mining Section, Fuel and Explosives Service, Bureau of Mines.

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This paper is the fourth of a series[5/] that describes some methods and practices of mining coal mechanically where operations are conducted on more than one shift. Many inquiries have been received regarding methods of extracting pillars with mechanized equipment, and this paper deals primarily with this phase of mechanical mining. Some of the questions that have been asked are:

5/ Toenges, Albert L., and Anderson, Robert L., Multiple-shift Mechanical Mining in Some Bituminous-Coal Mines. Progress Report 1: Bureau of Mines Inf. Circ. 7014, 1938, 56 pp.
Toenges, Albert L., and Jones, Frank A., Multiple-shift Mechanical Mining in Some Bituminous-Coal Mines. Progress Report 2: Bureau of Mines Inf. Circ. 7067, 1939, 58 pp.
Toenges, Albert L., and Maize, Earl R., Multiple-shift Mechanical Mining in Some Bituminous-Coal Mines. Progress Report 3: Bureau of Mines Inf. Circ. 7178, 1941, 43 pp.

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1. Why has the percentage of recovery of coal from an area decreased in some mines and increased in others when a change has been made from hand to mechanical loading?

2. Can the method of extracting pillars by hand be adapted to machine loading?

3. Are fewer tons produced per unit in mines where pillars are extracted?

4. Does extraction of pillars by machine introduce additional hazards?

The purpose of this and subsequent investigations is to find, if possible, an answer to these questions. An analysis of methods and systems at mines operating under various physical conditions offers a basis of approach to the answers to these questions.

ACKNOWLEDGMENT

The information used in preparing this paper was obtained through the courtesy and cooperation of the officials of the companies whose mines are described. Consent of the executives to publish these data was obtained.

DESCRIPTION OF MINES

Mines have been numbered beginning with 35, because the last mine described in Progress Report 3, Information Circular 7178, was 34.

Mine 35

The mine is opened by four 350-foot shafts and has an average cover of 450 feet. The coal bed, which averages 64 inches in thickness, contains two small bands of impurities about 6 inches apart, 18 to 20 inches from the bottom of the bed. The coal bed is overlain by 12 to 18 inches of shale commonly called draw slate. The immediate roof strata, which comprise several beds of carbonaceous and sandy shales and two thin beds of coal, are about 12 feet thick. The floor is soft fire clay, which flows under pressure and disintegrates rapidly when exposed to the air.

The draw slate will not support itself and must be removed following loading. The immediate roof is fragile, and systematic timbering is required when the width of openings exceeds 10 feet.

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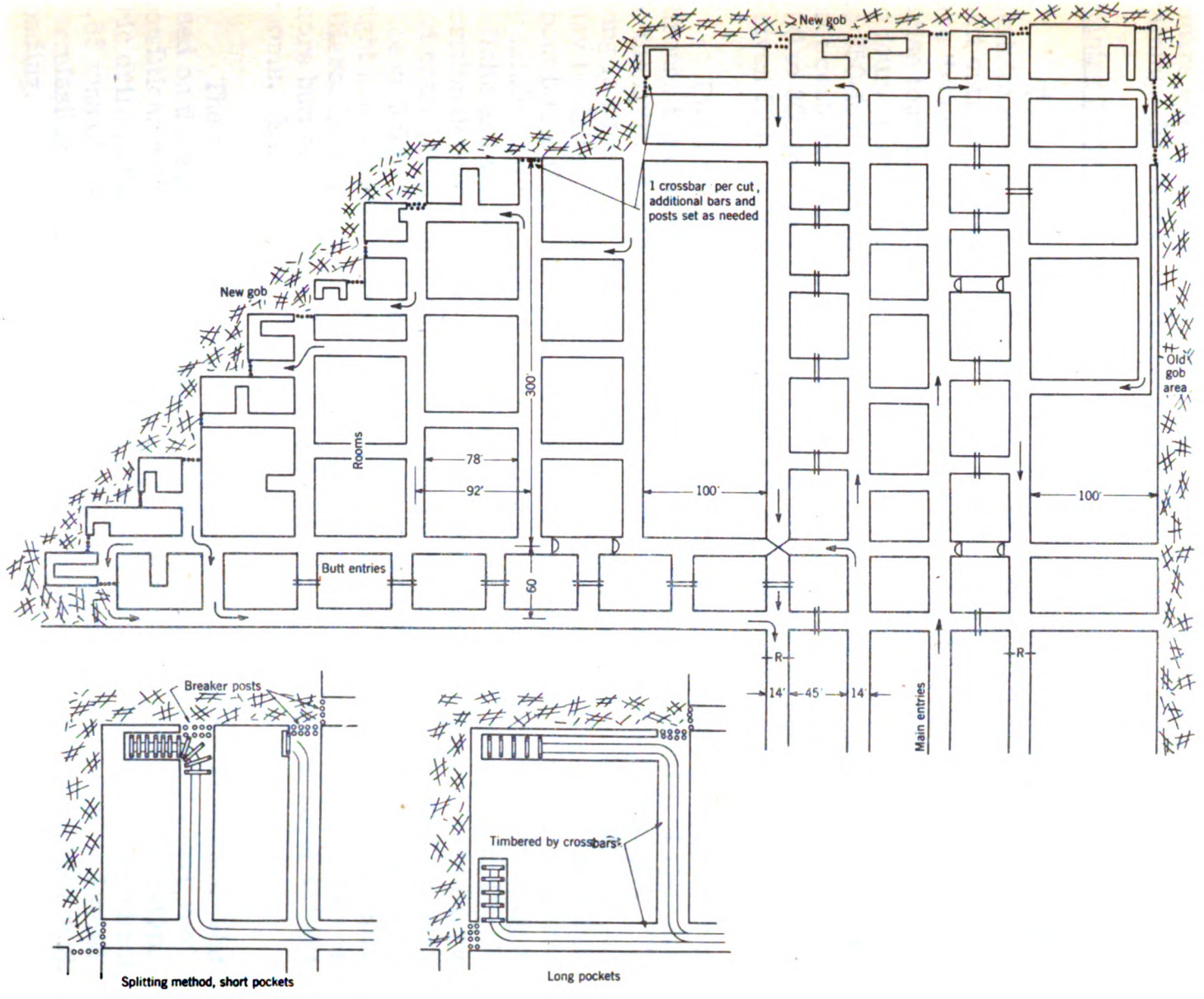

Figure 1.—Method of mining at mine 35.

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The average production per day of two shifts is 3,300 tons, which is loaded mechanically by crawler-mounted, mobile loading machines. The entire output at the time the mine was visited came from pillars in retreat mining. Recovery is estimated at 80 to 85 percent.

Mining Method

The mine is carefully planned and projected to take advantage of the definite cleats of the bed. The property is sectionalized by main face and butt entries at right angles. From these entries other face and butt entries are driven at intervals of 1,600 to 2,300 feet. The main entries usually comprise four to six parallel headings, and submain entries are in sets of three to four. Butt entries from which rooms are driven are in pairs on 300- to 350-foot centers. Rooms and crosscuts are usually driven on 60- or 90-foot centers. Barrier pillars protecting main or submain entries range from 100 to 300 feet in width, depending on conditions. All entries and rooms are driven 12 to 14 feet wide. Rooms are 300 feet deep.

Pillars are mined by the pocket-and wing method. The pillar is split through the center, and a pocket is driven in the inby portion at right angles to the split. A thin pillar or wing is left between the pocket and gob. This wing is recovered after the pocket has been completed. (See fig. 1.) A pocket may be driven along both inby sides of the pillar, leaving a pillar or fender about 5 to 6 feet thick between the pocket and the gob. The fender is recovered by mining from the inby end. (See fig. 1.) Pillars are extracted along a definite and well-maintained, stepped rib line. The line varies in length and position depending upon the kind of pillars being removed. Where barrier and chain pillars of submain or main entries are extracted, the line may not exceed 400 to 500 feet in length, and its position usually is approximately at right angles to the entries. During the extraction of room-and-butt chain pillars, the line may be 1,500 to 1,800 feet long, extending across two or more butt entries, and its position is usually at an angle of about 45° to the rooms. (See fig. 1.)

The coal is cut by track-mounted, arc-wall mining machines. Water is used on the cutter bar. Shortwall mining machines are used where roof conditions will not permit top cutting. The face is drilled by auger-type electric drills, and the coal is blasted in a permissible manner. Approximately 3.85 tons of coal is produced per pound of explosive. The coal is loaded by permissible mobile loading machines, and water is used on the face during loading.

Gathering locomotives are of permissible storage-battery type. A locomotive transports as many as seven cars to the loading machine. One car

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at a time is loaded and switched at an outby point. After the cars have been loaded, the trip is transported to a storage track. A relay locomotive operates between this storage track and the main-line sidetracks. Main-line haulage is done by electric-trolley locomotives. Mine cars have an average capacity of 2.75 tons. All electric-trolley haulage is done on intake air.

The cycle of mining for each loading unit is: (1) Timber, (2) lay track, (3) cut, (4) drill, (5) blast, (6) load, and (7) haul. The crew of men usually used to perform this cycle is classified as follows:

Timberman and helper	2
Trackman and helper	2
Mining-machine operator and helper	2
Driller and helper	2
Shot firer	1
Loading-machine operator and helper	2
Motorman and brakeman	2
Face boss	1
	14

All places are timbered with three-piece sets on 4-foot centers, and additional crossbars and posts are set at the face as required. Timbers are set to support the draw slate over the cut while the coal is being loaded; then this draw slate is taken down and loaded, or it is gobbed, where possible. Approximately 6.6 tons of coal are produced per post used and 82.5 tons of coal per crossbar.

The loading operations are summarized as follows:

Average number of cars loaded per shift per unit	65
	Percent of time
Loading	23.3
Squirming	19.5
Delays	11.3
Car change	25.2
Place change	20.7
	100.0

The mine is rated as gassy and is ventilated by two fans on the surface. These fans circulate about 490,000 cubic feet of air per minute at 3 inches water gage through 15 splits. The methane content of the air of each split is

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checked daily. If the methane in a split exceeds 0.5 percent, the men are removed from that split until the condition is remedied.

All mining equipment at the face is the permissible type, is inspected regularly and is kept in permissible condition.

Electric power is purchased, and 10.1 kw.-hr. is used per ton of coal produced.

Classification of employees

Classification	Coal			Rock			Total
	Day	Night	Total	Day	Night	Total	
Underground:							
Loading-machine men	26	26	52	9	9	18	
Mining-machine men	26	26	52				
Drillers	26	26	52				
Motormen and brakemen	26	26	52	3	3	6	
Shot firers	12	11	23				
Trackmen and helpers	26	26	52				
Timbermen	26	26	52	5	5	10	
Unit foremen	12	11	23				
Total men on mechanized units	180	178	358				
Other underground employees:							
Motormen and brakemen	12	12	24				
Dispatcher	1	1	2				
Trackmen and helpers	3	3	6				
Road cleaner and helper	5	3	8				
Masons and bratticemen	9	7	16				
Timbermen	9	8	17				
Slatemen	2	1	3	11	11	22	
Laborers	2	1	3				
Drivers				4	3	7	
Pumpers and pipemen	7	7	14				
Wiremen and battery charger	3	3	6				
Greasers	3	2	5				
Cagers and bottom men	4	4	8				
Mechanical repairmen	10	6	16				
Supervision, foremen and firebosses	8	7	15				
Total other underground employees, coal	78	65	143				
Total underground employees	252	233	488	32	31	63	551

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Classification	Day	Night	Total
Surface:			
Hoisting engineers	2	3	5
Top cagers	1	2	3
Tipplemen	14	13	27
General labor	13	0	13
Cleaning-plant men	5	3	8
Repairmen: Lamps, electrical, mechanical	16	10	26
Clerical	6	1	7
Engineers	3	0	3
Supervision	2	1	3
Total surface employees	62	33	95
Total employees			646

Summary

Percentage of mine mechanized	100
Average daily production, raw coal, tons	3,300
Loading machines, loading coal	13
Loading-machine shifts per day	26
Average number of men per unit per shift	13.75
Man-shifts per day on mechanized units, coal	358
Average production per day per man on mechanized units, tons	9.2
Total employees underground	551
Average production per man per day, underground, tons	5.98
Total employees, underground and surface	646
Average production per day per man employed, tons	5.1

Mine 36

The description that follows applies to two mines, designated A and B. The physical conditions and method of mining are similar, but operating equipment varies. Both mines work two shifts daily. Mine A produces 3,500 tons daily and mine B, 2,100 tons daily. All of the coal is loaded mechanically from pillars in retreat mining. At mine A, five track-mounted and one crawler-mounted loading machines are used, and at mine B three track-mounted machines are supplemented by one crawler-mounted loading machine. All loading machines are the permissible type. The coal bed averages 108 inches in thickness and is overlain by 12 to 24 inches of shale, locally termed "draw slate." The material above the draw slate, comprising alternate layers of shale and coal, is 12 feet thick. This material is fragile and must be supported by timbering where openings exceed 10 feet in width. The bottom is fire clay. The bed, which has an average cover of 200 feet, is horizontal but has local dips as great as 13 percent.

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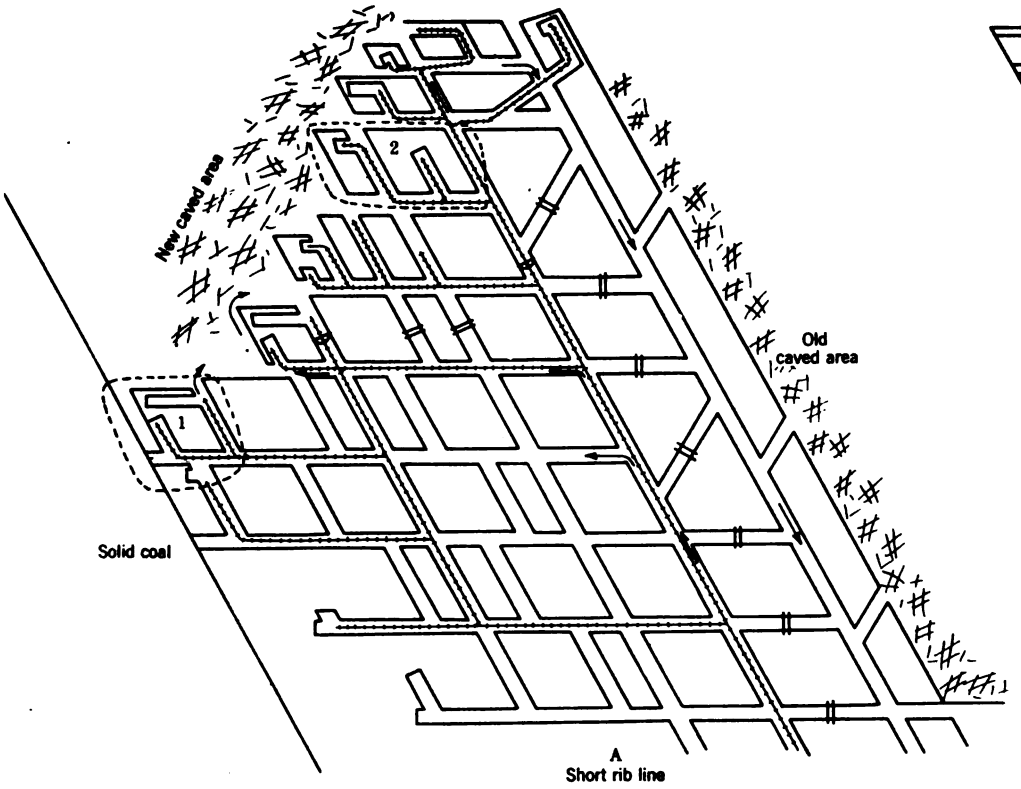
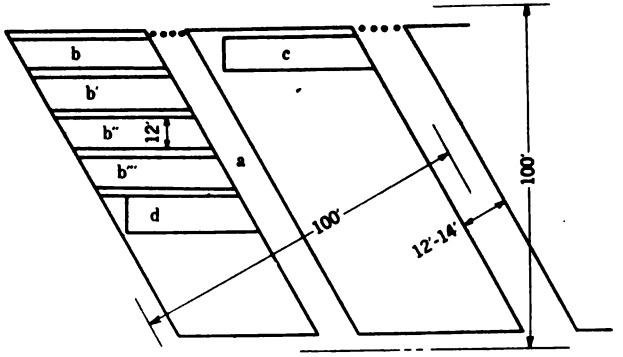
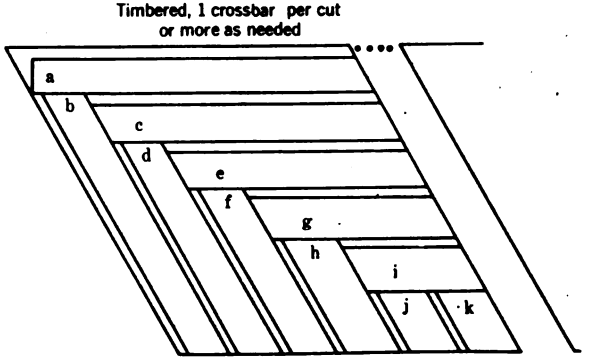


A
Short rib line



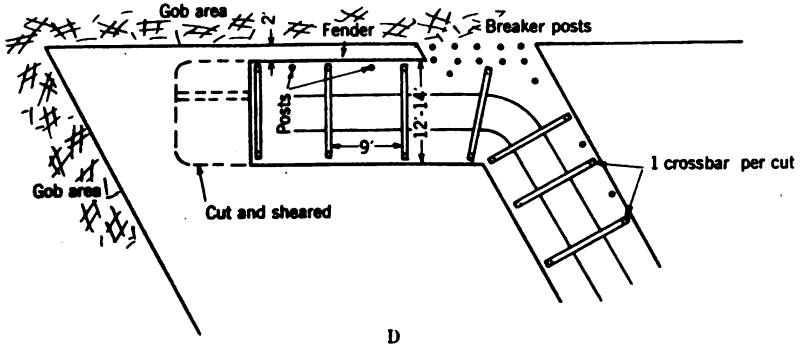
a-Split in block
b to b'''-Mining quarter block
c-First cut-over on second half block
d-Simultaneous with c

B
Block removal by splitting area 2 of A



Cut-overs in sequence, a and b, c and d, and so forth

C
Block removal by cut-overs, area 1 of A



D
Detail of cut c of B

Figure 2.—Method of mining at mines 36A and 36B.

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Mining Method

Mine A is opened by two shafts and a drift. One shaft serves for coal hoisting and air intake; the other shaft is partitioned by an incombustible curtain wall. The intake-air side serves for hoisting men and supplies, and the other side is used for return air to the fan. The drift opening, used for hauling from an isolated portion of the property not connected to the main body of coal, is an intake airway. The shafts at mine B are similarly arranged as at mine A. With few exceptions, openings are driven 12 to 14 feet wide on 100-foot centers. Room crosscuts and entries usually are driven on an angle of about 63°, which results in diamond-shaped blocks, as shown in figure 2,A.

The properties are developed by driving multiple entries to the boundaries, where retreat operations are started. Rooms and crosscuts are developed a short distance in advance of the retreating rib line as needed. The blocks are mined by splitting through the center and mining the half blocks in sequence (as shown in fig. 2,B) or by long slices or "cut-overs" on the inby sides of the block (as shown in fig. 2,C). The choice of method depends on the roof conditions in the block. Where the pillar is heavily loaded and the roof is highly stressed, the first-mentioned method is employed. Where the roof is less-stressed, the latter method is followed. Careful attention is given to the sequence of extraction of blocks to make certain that the points of the blocks projecting into the gob area fall on a straight line.

The coal is cut by means of track-mounted arcwall mining machines, which make three cuts in each place - one shear, one top cut, and one bottom cut. The top cut is made approximately 12 inches below the draw slate, and the bottom cut usually is made about 8 feet below the top cut. The quality of the coal left in the top and bottom is inferior. Where the draw slate cannot be protected by coal, it is usually taken down immediately following the loading cycle.

The cycle of mining is as follows: (1) Timber, (2) lay track, (3) cut, (4) drill, (5) shoot, and (6) load.

The unit crew that performs this work is classified as follows:

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Mine A	Mine B
1 foreman	1 foreman
2 loading-machine men	2 loading-machine men
4 transportation men (2 locomotives)	2 transportation men
2 mining-machine men	2 mining-machine men
4 trackmen	4 trackmen
2 timbermen	4 timbermen
1 driller	1 driller
1 shot firer	1 shot firer
2 clean-up men	2 clean-up men
19	19

The clean-up men follow the loading machine and load by hand, on tonnage rate, coal left or spilled by the loading machine.

The coal is loaded directly into mine cars by the loading machines. At mine A two locomotives are used to serve each loading machine, at mine B only one locomotive is used with each loading machine.

The working places are carefully timbered with three-piece sets. Approximately 10 tons of coal is mined per prop used and about 28 tons per crossbar.

Both mines are rated as gassy, and permissible equipment is used in the working places. The mines are ventilated though numerous splits by exhausting fans.

Loading operations are summarized as follows:

	Mine A	Mine B
Average number of cars loaded per unit per shift	94	82
Mine-car capacity (as loaded), tons	3.2	2.75
	Percent of time	
Loading	33.21	31.78
Squirming	3.42	4.63
Delays	22.67	28.60
Car change	23.50	23.10
Place change	17.20	11.89

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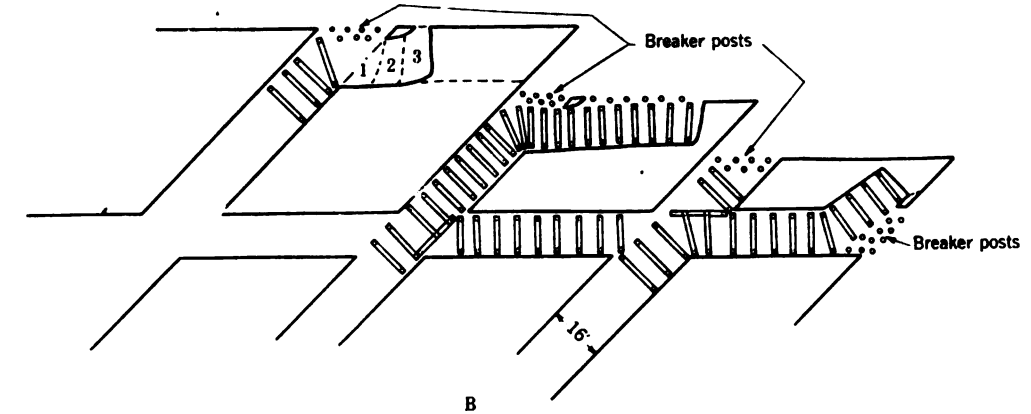
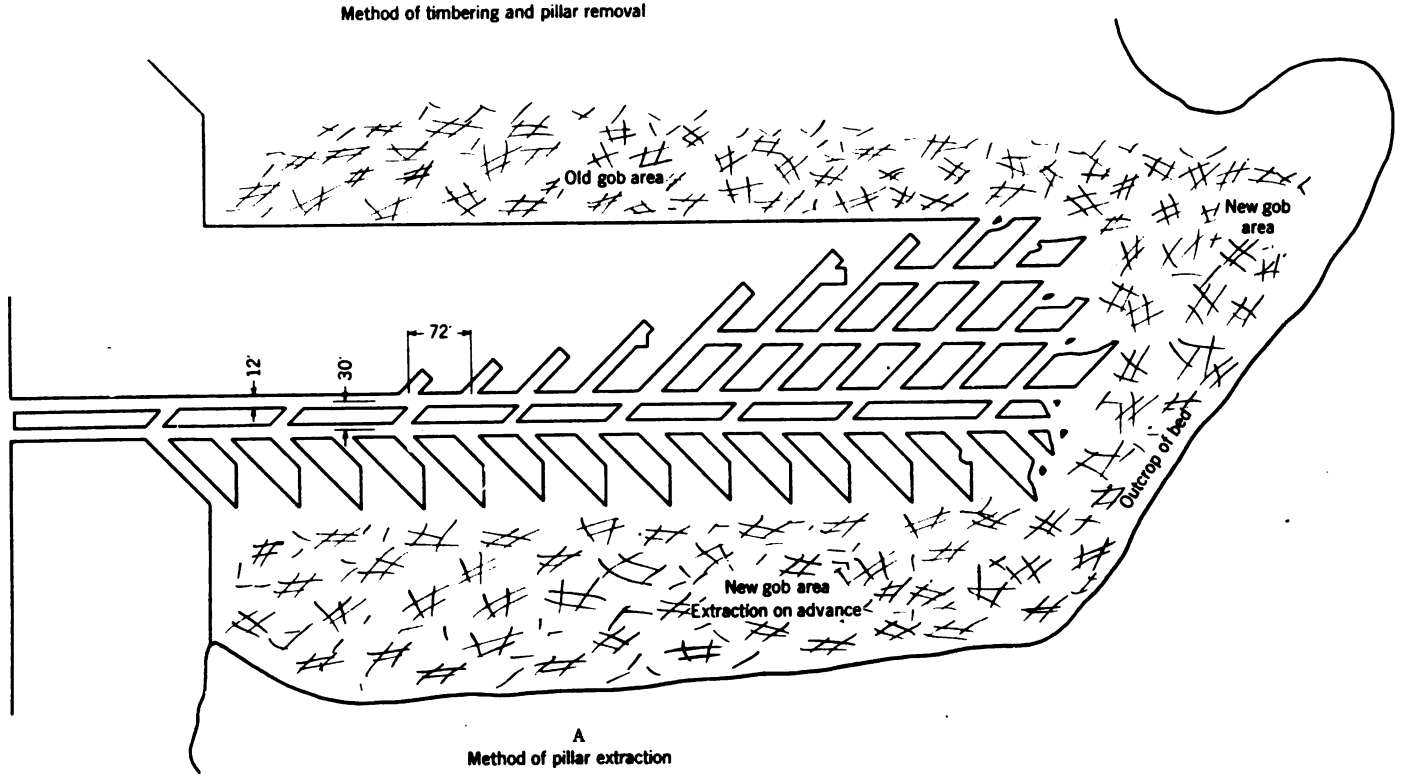


B
Method of timbering and pillar removal



A
Method of pillar extraction

Figure 3.—Method of mining at mine 37.

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Summary

	Mine A	Mine E
Percentage of mine mechanized	100	100
Average daily production, tons	3,500	2,100
Loading machines	6	4
Loading-machine shifts per day	12	8
Average number of men per unit per shift	19	19
Man-shifts per day on mechanized units	228	152
Average production per day per man on mechanized units, tons	15.4	13.8
Total employees underground	318	194
Average production per day per man, underground, tons	11.0	10.8
Total underground and surface employees	366	229
Average production per day per man employed, tons	9.5	9.2

Mine 37

The coal bed, which outcrops on the side of valleys, ranges in thickness from 60 to 84 inches and contains one or two partings varying in thickness. When the mine was visited, mining was being done in sections where only one parting occurred and the coal bed averaged 6 feet in thickness. The stratum immediately above the bed is sandy shale, 2 to 72 inches thick, containing lenses and stringers of coal. Above this material is a sandstone stratum. In parts of the mine the sandy shale is absent, and the sandstone forms the immediate roof. The bottom is sandy shale.

The daily output averages 1,320 tons from three working sections of the mine. Approximately two-thirds of the tonnage is from pillars, and one-third is obtained from advance work. The estimated recovery on present work is 92 percent.

The room-and-pillar system of mining is used. The workings are confined to areas bounded by the irregular outcrop of the bed. Entries are driven 12 feet wide on 30-foot centers, and rooms are turned on 72-foot centers at an angle of 45°. Rooms are driven 15 feet to 18 feet wide. The first crosscut in rooms is usually turned at 70 feet, and additional crosscuts are turned on 90-foot centers. All crosscuts are turned at 45° from the rooms. (See fig. 3,A.)

All working places are timbered with rows of timbers set on 4-foot centers. Where the roof is fragile, 4-inch by 12-inch by 12-foot crossbars are used. In extracting pillars, the size of the crossbar is increased to 8 inches by 8 inches by 18 feet. Additional safety posts are used as required.

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Timbers are recovered with a truck-mounted electric hoist and steel rope by a crew of men. The amount of timber used varies, but approximately 8.43 tons and 39 tons of coal are produced per prop and crossbar, respectively.

The coal is cut in a hard shale parting ranging from 4 to 8 inches in thickness. This parting occurs approximately 3 feet above the bottom of the bed. The lower bench of the bed usually is sheared in line with the left rail of the track. Cutting is done with track-mounted machines equipped with bars ranging in length from 7-1/2 to 11-1/2 feet. The average depth of the cut is 7 feet. Throw-away cutter bits are used. An average of two sets of bits are used per machine shift.

The face is drilled with a post-mounted, electric, 3-inch auger drill equipped with a "mole" foot bit. Usually four holes are drilled in the bottom bench, one of them between the shear and the rib; two holes are drilled in the upper bench, one at each rib. The cuttings are loaded by hand into mine cars, and the bottom and kerf are swept to prevent impurities being loaded with the broken coal. The coal is broken with Cardox, the lower holes being shot first. After the coal in this part of the bed is loaded, the upper section is broken and loaded.

The coal is loaded into 2.7-ton-capacity, steel, end-dump cars by track-mounted, mobile loading machines. Each loading machine is serviced by a 6-ton cable-reel locomotive, which transports five cars per trip. One car is loaded at a time. Switches and track are laid in each crosscut, and cars are changed at the nearest crosscut. This practice limits the one-way car change to approximately 90 feet. Trips of cars are brought to the working section by a main-line locomotive, and coal is stored at the sidetrack nearest the working section.

When the mine was visited, the three loading machines were operating seven machine-shifts in 24 hours. The schedule of operation is shown graphically in figure 4, and table 1 is a detail of the number of men performing the operations shown in figure 4.

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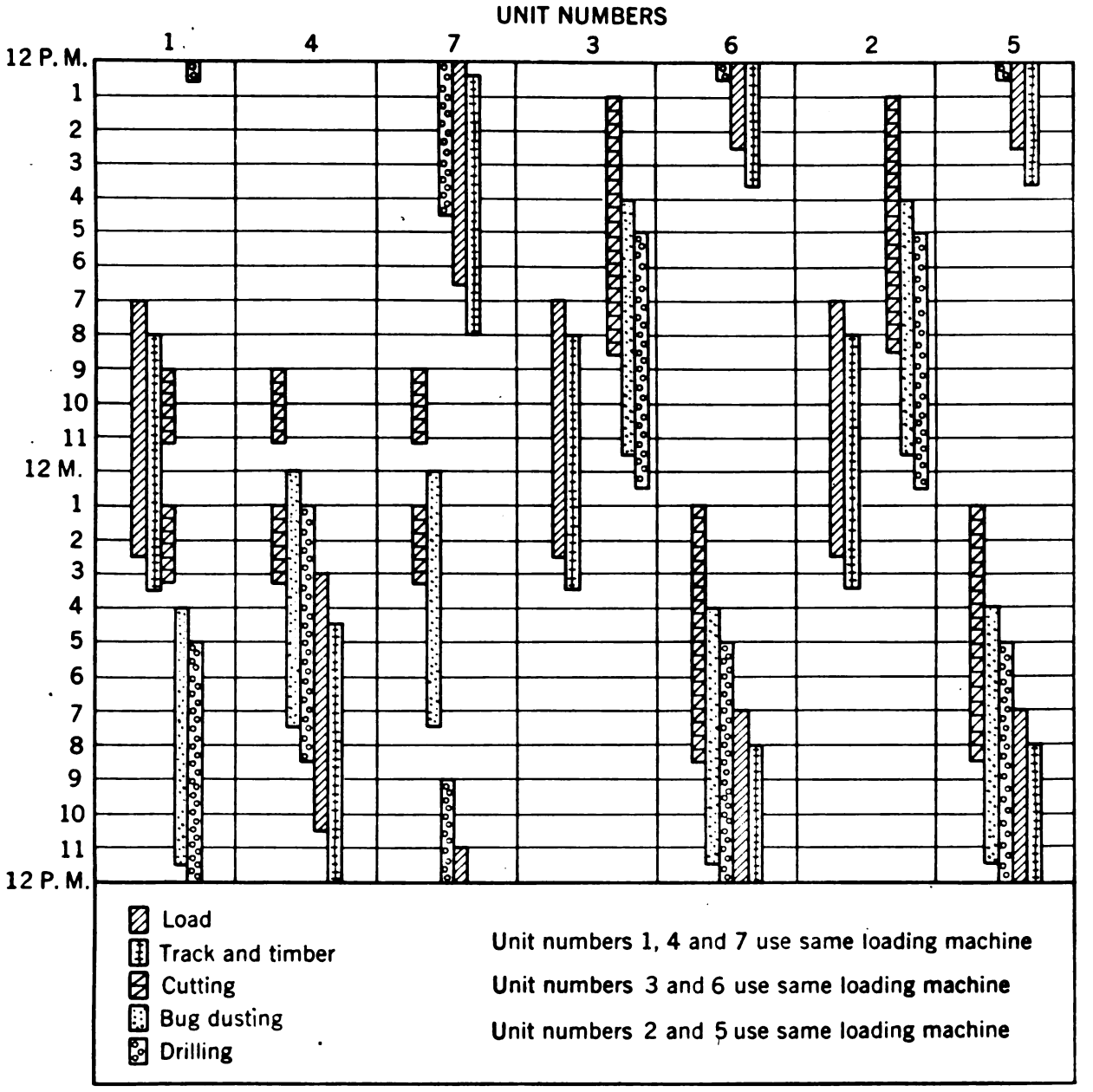

Figure 4.—Working schedule at mine 37.

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TABLE 1. - Summary of figure 4 (24-hour period)

Time	Unit	Number of men						
		Loading	Transportation	Track and timber	Bug-duster	Drilling	Foreman and shot firer	Cutting
7:00 a.m.	1	2	2				1	
	2	2	2				1	
	3	2	2				1	
8:00 a.m.	1			4				
	2			4				
	3			4				
9:00 a.m.	1							2/3
	4							2/3
	7							2/3
12:00 noon	4				5			
	7				4			
1:00 p.m.	1							2/3
	4					2		2/3
	5							2
	6							2
	7							2/3
3:00 p.m.	4	2	2				1	
4:00 p.m.	1				6			
	5				5			
	6				5			
4:30 p.m.	4			4				
5:00 p.m.	1					2		
	5					2		
	6					2		
7:00 p.m.	5	2	2				1	
	6	2	2				1	
8:00 p.m.	5			4				
	6			4				

See footnote p. 14.

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TABLE 1. - Summary of figure 4 (24-hour period) Cont'd.)

Time	Unit	Number of men						
		Loading	Transportation	Track and timber	Bug-duster	Drilling	Foreman and shot firer	Cutting
9:00 p.m.	7					2		
11:00 p.m.	7	2	2				1	
12:30 a.m.	7			4				
1:00 a.m.	2							2
	3							2
4:00 a.m.	2				6			
	3				6			
5:00 a.m.	2					2		
	3					2		
		14	14	28	37	14	7	12

Note: Units 3 and 6 use same loading machine, units 2 and 5 use same loading machine, and units 1, 4, and 7 use same loading machine.

An average unit crew comprises the following:

1	foreman and shot firer
1	loading-machine operator
1	loading-machine helper
1	cutting-machine man
1	cutting-machine helper
1	driller
1	driller's helper
1	trackman and timberman
3	trackman's and timberman's helpers
1	motorman
1	brakeman
3 to 5	bug dusters
16 to 18	

The output of each loading machine per shift averages 189 tons of coal as well as 10 cars of rock from roof falls and gob. The cutting for the seven loading-machine shifts is done in six cutting-machine shifts.

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Pillar Extraction

The usual plan of operation is to develop rooms off one of a pair of entries on the advance and to extract pillars as soon as the rooms have been driven to a predetermined limit. The pillars from the face outby to the first crosscut are extracted, leaving the outby room pillar to be extracted together with the entry chain pillar on the retreat from the area. After the coal has been mined from the one entry on the advance, the pillars from the area off the other entry of the pair are extracted on the retreat.

The coal is mined from pillars by a modification of the open-end method, in which a small, triangular stump is left on the gob side during the first three cuts when starting across the pillar. (See fig. 3,B.) This is usually removed by hand mining. Breaker rows of timber are set parallel to the track, and crossbars are erected on 4-foot centers across the working place. (See fig. 3,B.) Pillars are extracted in sequence to maintain a straight rib line.

At this mine recovery by mechanical means has been greater than by hand loading. During hand-loading operations pillars were extracted by the fender-and-pocket method, and the fenders left between the pocket and gob usually were lost. The rapidity with which the cuts are now made across pillars permits maximum extraction before the weight of the overburden acts upon the immediate roof. Recovery of timber is also made possible, and falls along the rib line are accomplished, thus relieving the load on the unmined pillars.

Ventilation of the mine is sectionalized, and the air is exhausted by three 6-foot, propeller-type fans situated at openings on the outcrop of the bed. The main haulageway and numerous outcrop openings form the intakes.

Track in working places is constructed with 30-pound rails on steel ties. The main-line track is constructed with 60-pound rails on wooden ties. The distance of the haul from face to tipple averages 2-1/2 miles. The cars are dumped at a cross-over dump, and the coal is lowered to the tipple by a flight conveyor.

Electric power is purchased and is converted from alternating current to 250-volt direct current for mine use by two 150-kilowatt rotary converters.

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Classification of employees (24-hour period)

Classification	First shift	Second shift	Third shift	Total
Underground:				
Loading-machine men	6	6	2	
Gathering locomotive	6	6	2	
Foreman and shot firer	3	3	1	
Trackmen and timbermen	12	12	4	
Cutting-machine men	12	-	-	
Bug-dusters	9	28	-	
Drillers	2	12	-	
Total men on mechanized units	50	67	9	126
Other underground employees:				
Main-line motormen	2	2	-	
Main-line brakemen	2	2	-	
Trackmen and helpers	3	3	-	
Slatemen	6	6	-	
Trapper	1	1	-	
Wireman	1	-	-	
Bratticeman	1	-	-	
Pumper	1	-	-	
Timber pullers	2	1	-	
Total other underground employees	19	15	-	34
Total underground employees				160
Surface employees:				
Coal dumpers	2	2	-	
Car droppers	2	2	-	
Slate dumpers and larrymen	2	2	-	
Lampmen	1	1	-	
Car repairman and helper	2	-	-	
Chief mechanic	1	-	-	
Mechanics	2	2	-	
Cardox reporter	1	-	-	
Supervision	1	1	-	
Tipplemen	6	6	-	
Tipple foreman	1	-	-	
Total surface employees	21	16	-	37
Total employees, underground and surface.				197

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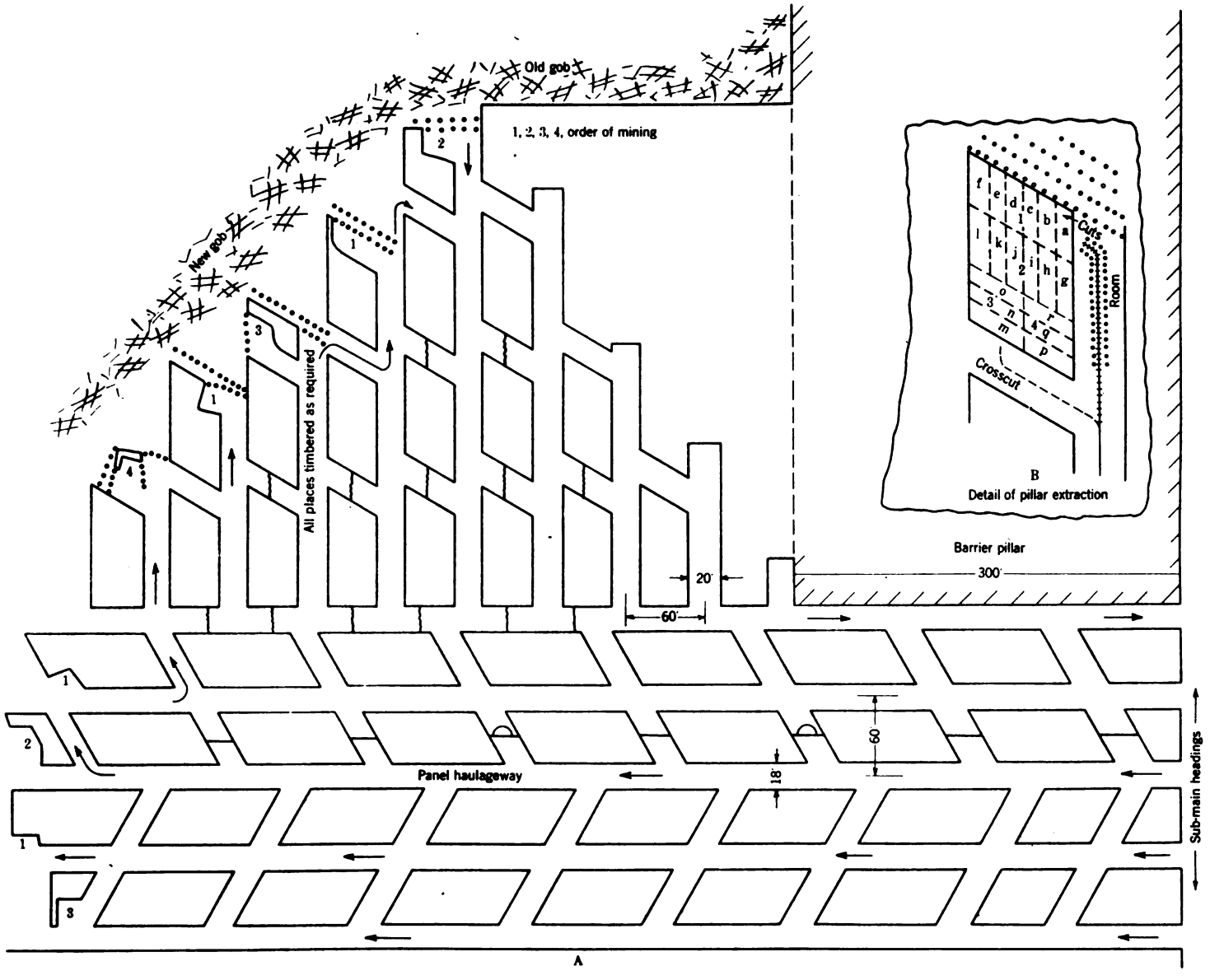

Figure 5.— Method of mining at mine 38.

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Summary

Percentage of mine mechanized	100
Average daily production of raw coal, tons	1,320
Loading machines	3
Loading-machine shifts per day	7
Man-shifts per day on mechanized units	126
Average number of men per unit per shift	18
Average production per man per day on mechanized units, tons	10.5
Total employees underground	160
Average production per man per day underground, tons	8.25
Total employees, surface and underground	197
Average production per man per day, tons	6.7

Mine 38

Daily production of the mine averages 4,719 tons, of which 76 percent (3,604 tons) is loaded mechanically by crawler-mounted loading machines.

The mine is in a mountainous region; and the coal bed, which averages 54 inches in thickness, outcrops approximately 550 feet above the valley. The strata overlying and beneath the bed are hard, sandy shales.

The main opening is a drift, and the mine is developed from main and submain entries that comprise two sets of three headings each. The headings are driven 18 feet wide on 60-foot centers, and each set is separated by an 80-foot pillar. Crossovers are driven through the pillar every 200 to 300 feet. Room entries, which are turned off the main entries, comprise five headings driven 18 feet wide on 60-foot centers. These entries are driven to the outcrop or a predetermined limit before rooms are developed. Extraction is on the retreat, and rooms are turned at 90° from one side of the room entries on 60-foot centers and driven 20 feet wide and 300 feet deep to the adjoining set of room entries or to the outcrop of the bed, where the workings are adjacent to the outcrop. Crosscuts between rooms are turned at 60°. A 300-foot barrier pillar is left to protect the main entries. (See fig. 5,A.)

Pillars are extracted by the open-end method, and the sequence in which they are mined is shown in figure 5,A. A detail of the method of extracting a pillar is shown in figure 5,B. Areas 1 and 2 of the pillar are mined from the room and areas 3 and 4 from the crosscut. The estimated recovery is 95 percent of the area of the bed.

All working places are timbered with posts set on 4- to 5-foot centers, a row on each side of the track. Caps 3 by 8 by 24 inches are used on each

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post. An average of one prop is used for 6.29 tons of coal produced. In some places where the roof is fragile it is necessary to use 4-inch by 8-inch by 14-foot crossbars for support. An average of 47.19 tons is produced per crossbar.

When the mine was visited, 9 loading-machine crews were working on retreat mining and 4 crews were on development, a total of 13 machine crews. The 13 machines were operated on both the first and second shifts, and 2 of them were operated on the third shift. An average machine crew is as follows:

1	assistant foreman
1	loading-machine operator
1	loading-machine helper
1	cutting-machine man
1	scraper man
1	driller
1	shot firer
1	motorman
1	brakeman
1	trackman
1	trackman's helper
1	timberman
1	timberman's helper
13	

The faces are cut in the coal near the bottom of the bed by track-mounted cutting machines. The cutter bars of these machines are equipped with water sprays, which are supplied with water from a track-mounted tank that accompanies each cutting machine. These tanks are equipped with an electric pump, which forces the water to the cutter bar. Nine cutting machines cut the working places for 13 loading machines. The depth of the cut averages 7-1/2 feet, and the face is prepared for blasting by drilling three holes with a portable electric drill. Two holes are placed approximate ly 8 inches from each rib and one in the center. The two rib holes are collared 18 inches from the roof, and the center hole is drilled 12 inches from the bottom. The holes are charged with permissible explosive and are fired electrically. An average of 9.44 tons of coal is produced per pound of explosive.

The coal is loaded into 4-ton solid-end cars by 1-1/2-tons-per-minute-capacity loading machines. Each loading machine is serviced by a cable-reel locomotive. One car is loaded at a time, and these are switched at the room necks or crossover if the working place is an entry. Five or six cars are loaded per cut, and an average of 128.71 tons is loaded per machine shift. Three relay locomotives serve the working section from the main-line sidetracks.

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One hundred pounds of rock dust is applied by hand to the roof, ribs, and floor of the working place after each cut of coal has been loaded. In addition, a power-driven machine is used an average of nine shifts per week to apply rock dust throughout the mine workings.

The mine is ventilated by a 7-foot propeller-type fan and one 5-foot disk-type fan. Both fans are operated exhausting, and the intakes are the haulageways and mine openings to the outcrop.

The coal is transported by five trolley locomotives from the main-line sidetracks in the mine to the dumping station on the outside, where the cars are dumped singly, without uncoupling, in a rotary dump. The coal passes to a rope-and-button conveyor, which lowers the coal to a belt conveyor at the preparation plant in the valley.

Power for the operation is purchased, and the alternating current is converted to 275-volt direct current for underground use by three 200-kw. rotary converters.

Classification of employees (24-hour period)

Classification	First shift	Second shift	Third shift	Total
Underground:				
Loading-machine operator	13	13	2	
Loading-machine helpers	13	13	2	
Cutting-machine operators	9	9	1	
Cutting-machine helpers	9	9	1	
Scrapers	13	13	2	
Timbermen	13	13	2	
Timberman's helpers	13	13	2	
Drillers	13	13	2	
Shot firers	13	13	2	
Trackmen	13	13	2	
Trackmen helpers	13	13	2	
Motormen	13	13	2	
Brakemen	13	13	2	
Foremen	13	13	2	
Total employees on mechanized units	174	174	26	374

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Classification	First shift	Second shift	Third shift	Total
Other underground employees:				
5 main-line locomotives	10	10	2	
3 relay locomotives	6	6	2	
Timbermen	2	-	-	
Trackmen	11	5	4	
Bratticemen	3	-	-	
Supply men	-	-	3	
Powder men	-	-	3	
Wiremen	2	1	-	
Pumpers	1	1	1	
Dispatchers	1	1	-	
Rock dusters	-	-	2	
Total other underground employees	36	24	17	77
Total other underground employees chargeable to mechanized production				58
Total employees underground chargeable to mechanized production				432
Surface employees:				
Dumpers	1	1	-	
Sand-drier	1	1	-	
General labor	2	-	-	
Slate-dumpers	2	1	-	
Lamphouse men	1	1	-	
Outside tram operators (head house to valley)	2	2	-	
General foremen	1	1	-	
Tipple:				
Washery	1	1	-	
Pickers	6	6	-	
Car droppers	4	4	-	
Operator	1	1	-	
Greasers	1	1	-	
Mechanics	-	2	-	
Clean-up men	-	1	-	
Foremen	1	1	-	
Total surface employees	24	24	-	48
Total surface employees chargeable to mechanized production				36
Total employees, underground and surface, chargeable to mechanized production				468

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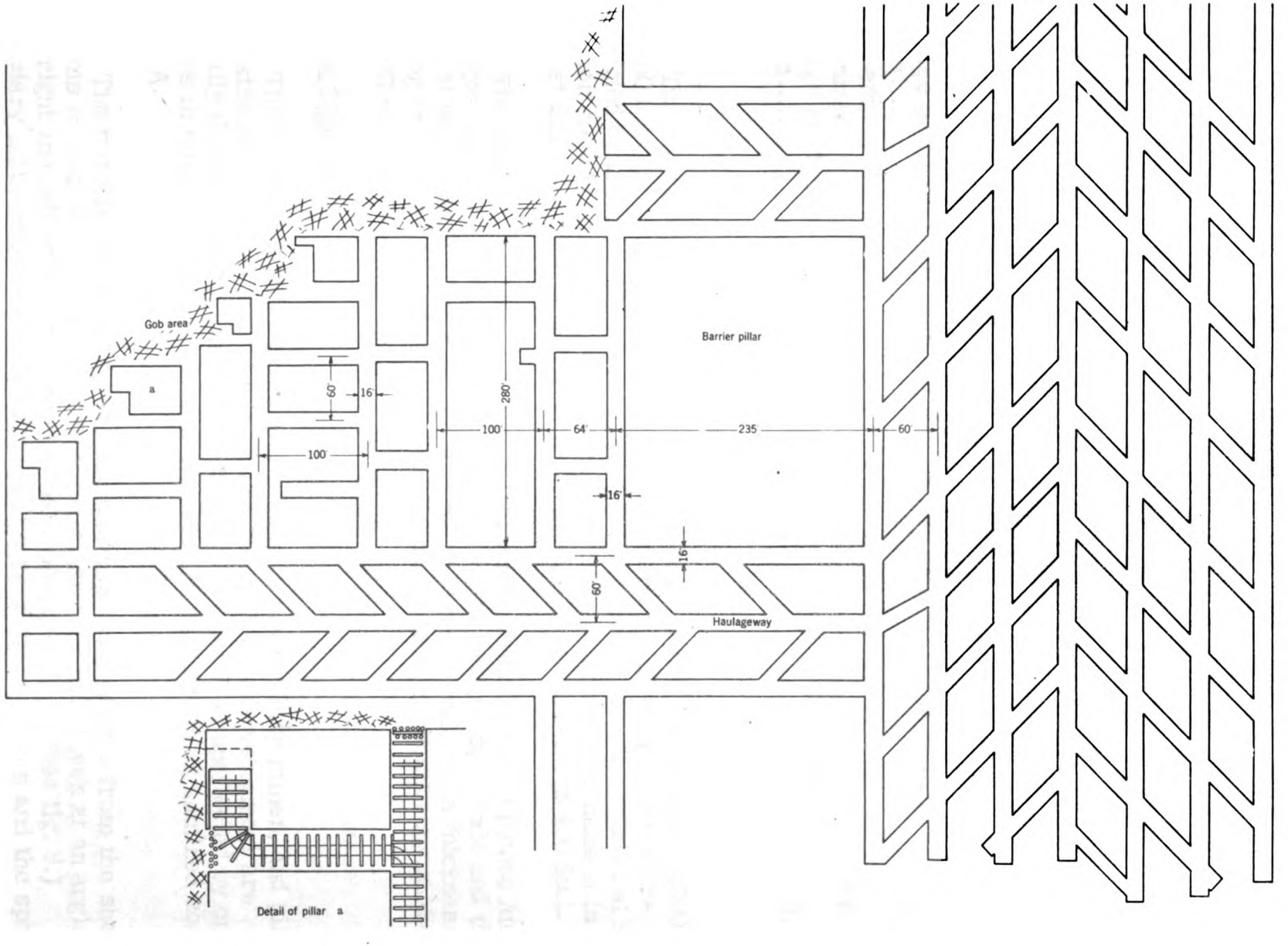

Figure 6.— Method of mining at mine 39.

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Summary

Mechanization of mine, percent	76
Average daily production from mechanized units, raw coal, tons	3,604
Loading machines	13
Loading-machine shifts per day	28
Man-shifts per day on mechanized units	374
Average number of men per unit per shift	13.35
Average production per unit per shift, tons	128.71
Average production per man per day on mechanized units, tons	9.64
Total employees underground chargeable to mechanized production	432
Average production per man per day on mechanized production, tons	8.34
Total employees underground and on surface chargeable to mechanized production	468
Average production per man per day on mechanized production, tons	7.70

Mine 39

The mines described here are designated A and B and produce 4,200 tons and 950 tons daily, respectively. The mines are subjacent and are interconnected by shafts to the surface; the coal is prepared for the market at a common cleaning plant on the surface. The average cover over mine A is 665 feet and over mine B 265 feet. The interval between beds is 400 feet.

The coal bed in mine A ranges in thickness from 60 to 160 inches and averages about 108 inches. The stratum below the bed is hard shale and that above it sandy shale. The coal bed in mine B is more uniform in thickness, ranging from 44 to 46 inches and is overlain by a hard carboniferous shale; the bottom is shale.

Mining Method

The room-and-pillar system of mining is used in both mines, and pillars are extracted. The method of mining and the system of development are virtually the same in both mines. Extraction in mine B is unaffected by operations in mine A, as the working portions of mine B are over unmined coal of mine A.

The mine is developed by driving multiple main entries from the shaft bottoms in sets of five to seven headings, with crosscuts driven at an angle, both right and left from the center on main haulage entry. (See fig. 6.) Secondary main entries are also driven in sets of five to seven and the spacing

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of sets is on about 2,000-foot centers. Room entries, in sets of three headings, are driven to the right or left from the secondary, depending on conditions, on about 400-foot centers. All entries are driven 16 feet wide on 60-foot centers. Barrier pillars left to protect main and secondary entries range from 200 to 250 feet in width and are extracted on retreat, as are room pillars.

When room entries have been developed their full distance rooms are turned from one side, and extraction of pillars is from the inby end of the entries. The first two rooms are developed on 64-foot centers and are connected by the normal number of crosscuts. A second pair of rooms is developed 100 feet outby the second room, leaving a solid block of coal between pairs of rooms. (See fig. 6.) This block is split by crosscuts on 60-foot centers in regular succession from the inby end as the rib line approaches. The blocks made by splitting and the room pillars are extracted in regular order by driving open-ended places, 16 to 20 feet wide, across the inby end of the block as shown in the detail of pillar A, figure 6. Frequently a thin pillar or shell of coal is left to prevent broken gob material from entering the working places. At the time mine A was visited, two loading machines were on pillar lines and four on development. At mine B two loading machines were in operation, both on pillars.

All working places are timbered with three-piece sets on 4- to 6-foot centers, or closer if necessary. Double rows of breaker posts are set at openings or ends of the blocks.

The coal is cut in the bottom of the bed by track-mounted mining machines equipped with a 9-foot cutter bar. The cutting crew and machine are used to assist in setting timbers in high places. The crossbar is placed on the end of the cutter bar raised into position against the roof, and held there by the bar until the supporting posts can be set.

The coal is blasted by Cardox, six holes being used in high coal (7 feet or more) and five holes in low coal. The holes are drilled by a regular driller using an electric, auger-type, post-mounted drill. The shots are fired by a shot firer.

The coal is loaded by track-mounted loading machines into mine cars. At mine A the average production per shift per machine is 350 tons and at mine B 190 tons. The capacity of the cars at mine A averaged 3.9 tons of raw coal and at mine B 2.4 tons.

A loading-machine section normally has six to nine working places either on development or on pillars. Each loading machine is served by two cable-reel gathering locomotives alternating in trips to the loading-machine. A trip

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comprised five cars. Main-line trolley locomotives transport the cars to side-tracks adjacent to the working sections.

The mines are interconnected and are ventilated by two fans. The coal-hoisting shafts serve as intake airways, and haulage ways are on intaking air circuits.

Classification of employees

An average section crew is as follows:

1 loading-machine operator
1 loading-machine operator's helper
1 mining-machine operator
1 mining-machine operator's helper
1 driller
1 shot firer
2 locomotive operators
2 brakemen
2 clean-up men
2 timbermen
2 trackmen
1 bratticeman
1 section foreman
18

The following labor is employed in 24 hours:

	First shift	Second shift	Third shift	Total
Underground mine A:				
Mechanical loading units	108	108	-	216
Other:				
Main-line locomotive operators	3	3	-	6
Main-line brakemen	3	3	-	6
Supply men	-	3	-	3
Trackmen	3	3	-	6
Pumpers	2	2	1	5
Wiremen	-	4	-	4
General labor	7	5	-	12
Firebosses	3	2	1	6
Foremen	3	1	-	4
Machinemen	2	-	-	2
Repairmen	-	18	-	18
Greasers	8	-	8	16
	142	152	10	304

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	First shift	Second shift	Third shift	Total
Underground, mine B:				
Mechanical loading units	34	34	17	85
Other:				
Brattciemen	1	-	-	1
Pumpers	1	1	-	2
Main-line locomotive operators	2	2	2	6
Main-line trackmen	2	-	-	2
Supply men	-	6	-	6
Wiremen	2	-	-	2
Repairmen	3	2	2	7
Dispatcher	1	1	-	2
Foremen	1	1	-	2
Firebosses	-	-	2	2
Total employees underground	47	47	23	117
Surface, both mines:				
Hoist engineers	3	2	2	7
Firemen	2	2	2	6
Machineshop men	10	6	3	19
Blacksmiths and car-repairmen	4	3	3	10
Machinists and welders	8	10	-	18
Electricians	5	-	-	5
Greasers	1	1	-	2
Tipplemen	5	5	-	10
	38	29	10	77

Summary

	Mine A	Mine B	Composite
Mechanization of mine, percent	100	100	100
Average daily production, mechanized units, tons	4,200	950	5,150
Mechanized units	6	2	8
Mechanized unit shifts per day	12	5	17
Average number of men per unit per shift	18	17	17.5
Man shifts per day on mechanized units	216	85	301
Average production per man per day on mechanized units, tons	19.4	11.2	17.1
Total employees underground	304	117	421
Average production per man per day underground, tons	13.8	8.1	12.4

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	Mine A	Mine B	Composite
Total employees, surface and underground[1/]	366.8	131.2	498
Average production per day per man employed, tons	11.4	7.2	10.3

1/ Surface employees on ratio to tonnage produced.

Mine 40

The coal beds in this mine occur in a series of anticlines and synclines, and the dip of the beds ranges from 0° to 24°. The maximum cover is 1,400 feet. The main opening is a slope driven in the upper bed for 5,000 feet, where the basin of the syncline is reached. The slope is then continued 400 feet through rock to the lower bed. The grade of the slope ranges from 6° to 17°. An auxiliary slope is driven along the axis of the syncline in the lower bed on a 5° dip for approximately 5,300 feet.

Operations are in two beds of coal approximately 240 feet apart. The upper bed averages 20 feet in thickness, but only the lower 5 feet of the bed is mined, as the upper 15 feet is stratified with "bony" and other impurities. The impure section of the bed is left for roof.

The lower bed, which averages 54 inches in thickness, contains a clay parting 5 inches thick 18 inches above the bottom of the bed. The lower section of the bed is free from impurities, but the upper part contains scattered lenses of pyrite. The bed contains cleavage planes that bear approximately 45° to the strike of the bed. The stratum above this bed ranges from hard, sandy shale to black shale having little strength. The bottom is hard, sandy shale.

The mine is 100 percent mechanized, and the average daily production of raw coal is 1,305 tons. Approximately 30 percent of the output is from workings in the upper bed or "new mine."

Mining Method

The room-and-pillar system of mining is used, and pillars are extracted. Pairs of entries that comprise the counter (air course) and gangway (haulage) are turned off the slopes at intervals of approximately 350 feet. The main entry or gangway is driven 20 to 24 feet wide, with a 40-foot coal pillar between the gangway and the counter, which is driven 12 to 14 feet wide. As a rule, the haulageway is brushed in the bottom, but if necessary some top rock is also taken to obtain a minimum clearance of 5 feet above the top of the rail. The brushing rock is usually gobbed on the low side of the entry. Entries are

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driven to a predetermined limit before extraction of the coal in the panel is begun, and they are driven along the strike of the bed on 0.5-percent grade to facilitate haulage and drainage. Rooms are turned on 55-foot centers, 30 feet wide, at 90° off the air course or counter, and these rooms are driven up the pitch of the bed to the haulageway of the entry above. Crosscuts between the haulageway and air course are driven 8 feet wide, and they are turned opposite the inby rib of the rooms. Room crosscuts are also driven 8 feet wide on 60-foot centers. (See fig. 7.) A working section generally consists of three rooms - two advancing and one retreating on the pillar.

A compartment comprising manway and conveyorway is securely timbered along the inby side of the rooms by erecting timber sets on 4- to 6-foot centers. These sets comprise three posts, one at each end of a 4- by 8-inch by 14-foot crossbar and one post placed about 5 feet from the rib. The area of the room outside the manway is timbered with heavy, round posts placed on approximately 4-foot centers. (See fig. 7.) A 6- by 6-foot timber crib is placed adjacent to the manway at each room crosscut.

All coal is loaded onto shaking conveyors comprising 10-foot pans connected with a link and pin. The loading pan of the conveyor is flattened on the side nearest the coal face, so that broken coal can flow onto the conveyor with the minimum of shoveling. The conveyors are driven by 20-horsepower electric motors, and in places where the dip of the beds is greater than 22° a wooden springboard is attached to the conveyor line. This springboard assists the motor on the upstroke and reduces the demand on the motor. The drive unit of the conveyor is erected in the crosscut opposite the room, and the conveyor is installed in the conveyorway adjacent to the inby rib of the room. A material track is placed in the manway compartment.

The cleavage in the bed results in forming a face approximately 45° to the direction of the room. The loading pan of the conveyor is turned along this face by means of a swivel. A cut 10 feet wide is made in the bottom of the bed at the innermost point of the face with a shortwall cutting machine equipped with a 7-foot cutter bar. Water is used on the bar to lay the dust. The face over the undercut is usually drilled with a portable, compressed-air, rotary drill or in some places with an electrically operated portable drill. The holes are charged with permissible explosive. Multiple blasting is done by means of a radio "B" battery. After the coal from this cut is removed, only a few scattered shots are necessary to loosen the remainder of the coal in the face. The bottom of posts used to support the roof in the working place is tapered (sniped). This practice permits gradual settling of the roof without breaking the posts. The weight of the overlying strata thus acts on the face, and the coal breaks along the cleavage planes without further cutting or the use of large quantities of explosives. Safety timbers are set along the conveyor line at the face to protect

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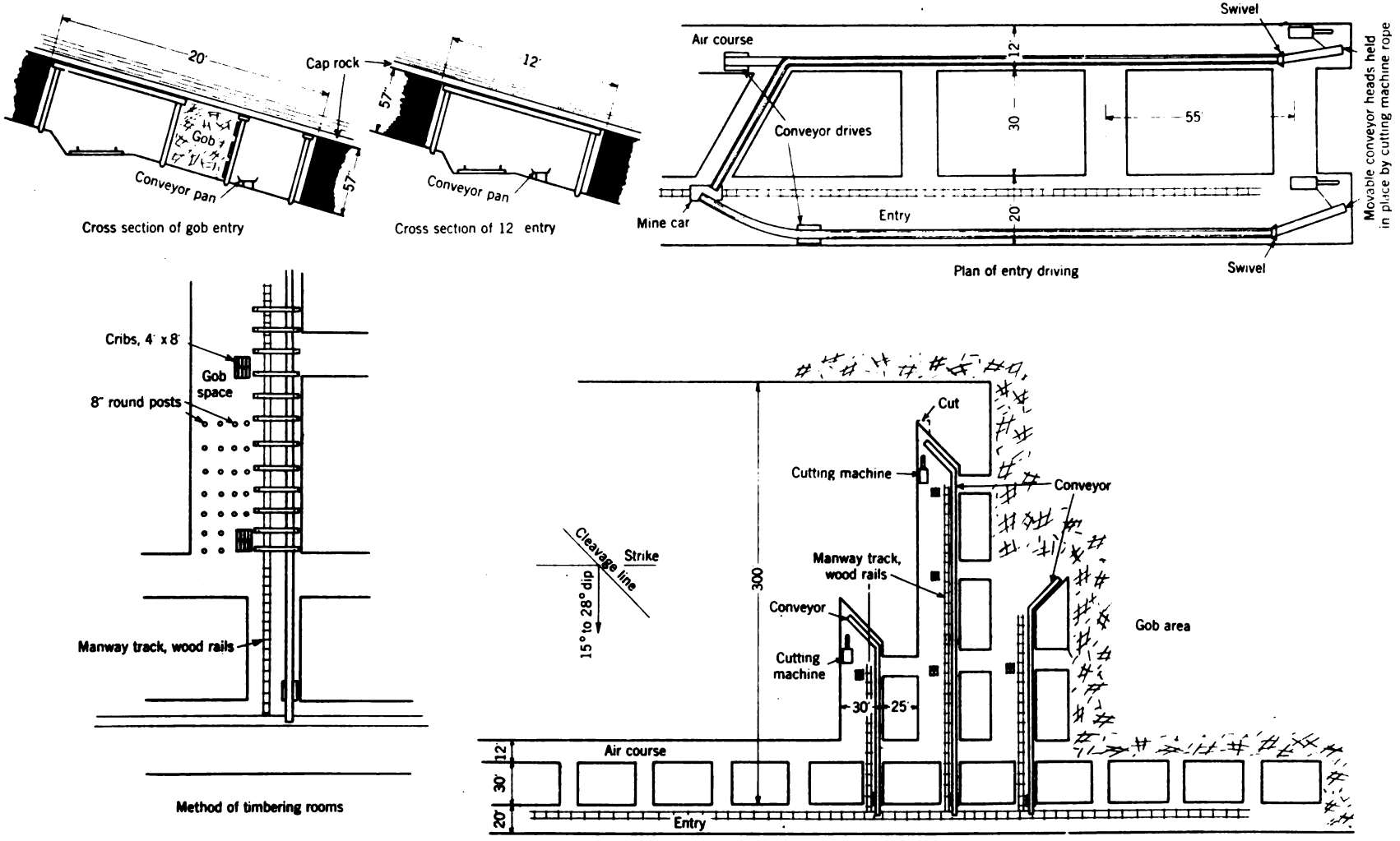

Figure 7.—Method of mining at mine 40.

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the workers. Approximately 5.9 tons is mined per prop. An average of 9.26 board feet of timber is used per ton of coal produced.

Pillars are extracted by mining across the pillar at an angle of approximately 60° off the center lines of the rooms. (See fig. 7.) It is usually unnecessary to cut during removal of pillars. All places are well-timbered adjacent to the conveyor line at the face.

Each working place is equipped with a cutting machine, portable drill, and supply truck. A sheave is attached to a timber at the head of the supply track in each working place, and one electric hoist handles supplies and material for three working places.

Electric power for cutting machines and electric drills, where such are used, is taken into the working place over power lines connected at junction boxes to main circuits in the entries. Where alternating current is used, all equipment is grounded with a fourth wire, which is connected to the main ground circuit. All electrical equipment in the working places is permissible.

The crew of men assigned to a room unit varies but is usually classified as follows:

2	facemen
1	machineman
1	conveyor runner and car trimmer
1	duckbill man
1	timberman
1	motorman
1	face boss
8	

The crew on pillar extraction usually includes:

1	conveyor runner and car trimmer
4	facemen
5	

These men perform any other duties that are necessary for the safe production of coal.

Shaking conveyors are also used in advancing entries. (See fig. 7.) Each heading is equipped with a shortwall cutting machine having a water spray on the cutter bar and a conveyor installed on the low side of each heading. After the face of the entry has been cut and blasted, loading is begun at its lower side.

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The loading pan of the conveyor has a swivel connection, and as loading progresses from the lower to the upper side of the entry this pan is held in the coal by means of the cable of the mining machine. This practice reduces the amount of hand shoveling of coal. One heading is prepared while coal is loaded in the other heading. An average of three cuts is loaded daily - two from one heading and one in the other. The entries are usually advanced 350 feet before the drives of the conveyors are moved ahead.

Coal is loaded into cars on the lower or haulage entry, and coal from the air course or upper heading is conveyed to the loading point by means of a swivel attached to the conveyor in the air course. The conveyor in the haulage entry has the pans mounted above the driving unit, thus raising the coal to the height necessary for loading into mine cars. The drive of the conveyor in the air course, however, is mounted in line with the conveyor and outby the turn that deflects the coal to the haulage entry. (See fig. 7.)

The crew assigned to a pair of entries comprising haulageway and air course is as follows:

2	loaders
2	cutting-machine men and drillers
1	timberman
1	car trimmer
1	transportation man (either motorman or hoistman)
1	foreman
8	

The bottom of the haulageway is brushed on the high side by a crew of three men, who also extend the track. This work is done on a single shift. The brushing is usually gobbed in the space between the roadway and conveyorway. (See fig. 7.)

The coal is loaded into cars that have an average capacity of 1.2 tons. The cars are transported in the entries by electric trolley locomotives, and trips of 16 cars are transported to the slope sidetracks, where the cars are sprayed with water. The trips of 16 cars are hoisted up the slope at an average speed of 2,600 feet per minute. Track gage is 36 inches, and the entry track is constructed with 30- and 40-pound rails on wood ties. The track in the slopes is built with 56-pound rails, also on wood ties.

Ventilation

The mine is ventilated by two fans - a 60- by 144-inch, double-inlet, centrifugal fan and a 64- by 112-inch-diameter centrifugal fan, both electrically

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driven and operated exhausting. Approximately 136,000 cubic feet of air per minute at 1.8 inches water gage is circulated in the mine. All haulage roads are on the intake of the ventilating system. Permanent stoppings are constructed of concrete.

Rock-Dusting

All entries and working places are rock-dusted. A small, portable compressed-air-operated, rock-dusting apparatus is used in pitch workings, where a track-mounted machine cannot be operated.

Classification of employees (24-hour period)

Classification	Rooms and pillars			Development			Grand total	Employees on mechanized units, percent
	Shifts			Shifts				
	Day	Night	Total	Day	Night	Total		
Underground employees:								
Loaders and duckbill men	34	13	47	15	6	21	68	44.7
Machine men	5	1	6	6	3	9	15	9.9
Conveyor runners	9	3	12	6	3	9	21	13.8
Face timbermen	9	3	12	5	2	7	19	12.5
Transportation	5	2	7	2	1	3	10	6.6
Timber-haulers	4	-	4	-	-	-	4	2.6
Unit foremen	4	2	6	6	3	9	15	9.9
Total employees chargeable to mechanized units	70	24	94	40	18	58	152	100.0

Classification	Day shift	Night shift	Total
Other underground employees:			
Brushers	-	2	
Trackmen and helpers	13	-	
Timbermen and helpers	5	-	
Main rope riders	3	2	
Inside rope riders	2	1	
Inside hoistmen	1	1	
Greaser	-	1	
Rope maintainer	1	-	
Sprinkler and pipeman	1	-	
Pumpers	-	2	
Firebosses	-	2	
Road cleaners	2	-	
Electrician and helpers	3	-	

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Classification	Day shift	Night shift	Total
Other underground employees: (Cont'd.)			
Haulage boss	1	-	
Mine foreman	1	-	
Assistant mine foreman			
Total other underground employees	34	11	45
Total underground employees			197
Surface employees:			
Tipplemen	14	3	
Blacksmith	1	-	
Welder	1	-	
Saw-filer	1	-	
Car-repairman	1	-	
Tipple foreman	1	-	
Hoisting engineer	2	2	
Firemen	3	1	
Lampmen	1	1	
Watchman	1	3	
Timber haulers and helpers	2	-	
Total surface employees	28	10	38
Total employees			235

Summary

Disposition of working time during a representative period is summarized as follows:

Duties	Percent of time
Working at face	83.1
Conveyor delays	9.7
Work other than at face	7.2
	100.0

Detail of work other than at face:

Classification	Percent of time
Moving conveyors	1.27
All repairs	1.18
Rock brushing	2.49

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Classification	Percent of time
Track laying	0.67
Moving hoists	.20
Pipe and wire extensions	.16
Moving machinery	.55
Recovering conveyor pans	.21
Rock dusting	.05
Splicing ropes	.07
Timbering	.07
Repairs to conveyor lines	.07
Chutes and stoppings	.17
Cleaning up	.04
Total	7.20

Production during period, tons of raw coal		23,344
Production from development, percent		39
Production from rooms and pillars, percent		61
Average production per man per shift, development, tons		6.33
Average production per man per shift, rooms and pillars, tons		9.70
		8.03

Summary for average working day:

Mechanization of mine, percent		100
Average daily production, raw coal, tons		1,605
Conveyor units		19
Conveyor shifts per day		28
Conveyor shifts per day, room-and-pillar	15	
Conveyor shifts per day, development	13	
Average number of men per unit per shift		5.42
Average number of men per unit per shift, room- and-pillar	6.26	
Average number of men per unit, per shift, development	4.46	
Man-shifts per day on mechanized units		152
Man-shifts per day on mechanized units, room-and-pillar	94	
Man-shifts per day on mechanized units, development	58	
Average production per man per day on mechanized units, tons		10.56
Average production per man per day on mechanized units, room-and-pillar, tons	11.43	
Average production per man per day on mechanized units, development, tons	9.13	
Total employees underground		197
Average production per man per day underground, tons		8.15
Total employees, surface and underground		235
Average production per man per day, tons		6.82

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Mine 41

Physical conditions in and surrounding the coal bed at this mine are similar to those at mine 40. The dip of the bed, however, is greater than at mine 40, being as much as 48° in some sections of the mine. The coal bed averages 57 inches in thickness and contains pronounced vertical cleats that strike approximately 45° to the dip of the bed. The overlying stratum is sandy shale, which is firm in some sections and weak in others. The bottom is fire clay.

The main opening of the mine is a double-track rock slope that intersects the coal bed at a point approximately 2,000 feet inby the portal. The slope is continued in the bed for 2,000 feet to the base of the syncline. At this point the cover is approximately 1,600 feet. An auxiliary slope is being driven along the axis of the syncline on a 12° dip. The maximum grade on the main slope is 33°.

Mining Method

In general, pairs of panel entries that comprise haulageway and airway are driven off the slope along the strike of the bed. These entries are driven on 1/2-percent grade in favor of the loads to facilitate haulage and drainage. The interval between pairs of entries ranged from 300 to 350 feet. The haulageway, which is the lower entry, is driven 22 to 24 feet wide, and the air course is 12 to 14 feet wide. The pillar between these headings is 40 feet wide. The haulageway is brushed in the bottom, and the rock is gobbed. Crosscuts between headings are driven 8 feet wide on 60-foot centers.

Coal is extracted from rooms and entries as in mine 40, except where the dip of the bed is greater than 28°. The mining system followed in sections where the dip is excessive is described.

Entry development. - The haulage entry is driven in the coal, and this opening is divided into three sections by rows of posts - the conveyorway, which is on the low side of the heading; the gob area, in which the bottom brushing is placed; and the track area, which is on the upper side of the heading. (See fig. 8.) The track area is approximately 8 feet wide, and the bottom is brushed 6 feet wide and to a sufficient depth to allow 5-foot clearance above the top of rail nearest the gob. The haulageway is timbered with three-piece sets on 4-foot centers. The conveyorway is approximately 6 feet wide from rib to props. These props are set on 4-foot centers and are lagged to prevent the gob from entering the conveyor way. The conveyor, an overdrive type, is erected along the rib and extends from the face to the hopper of an elevating conveyor. This elevating conveyor is of bucket type and transports the coal

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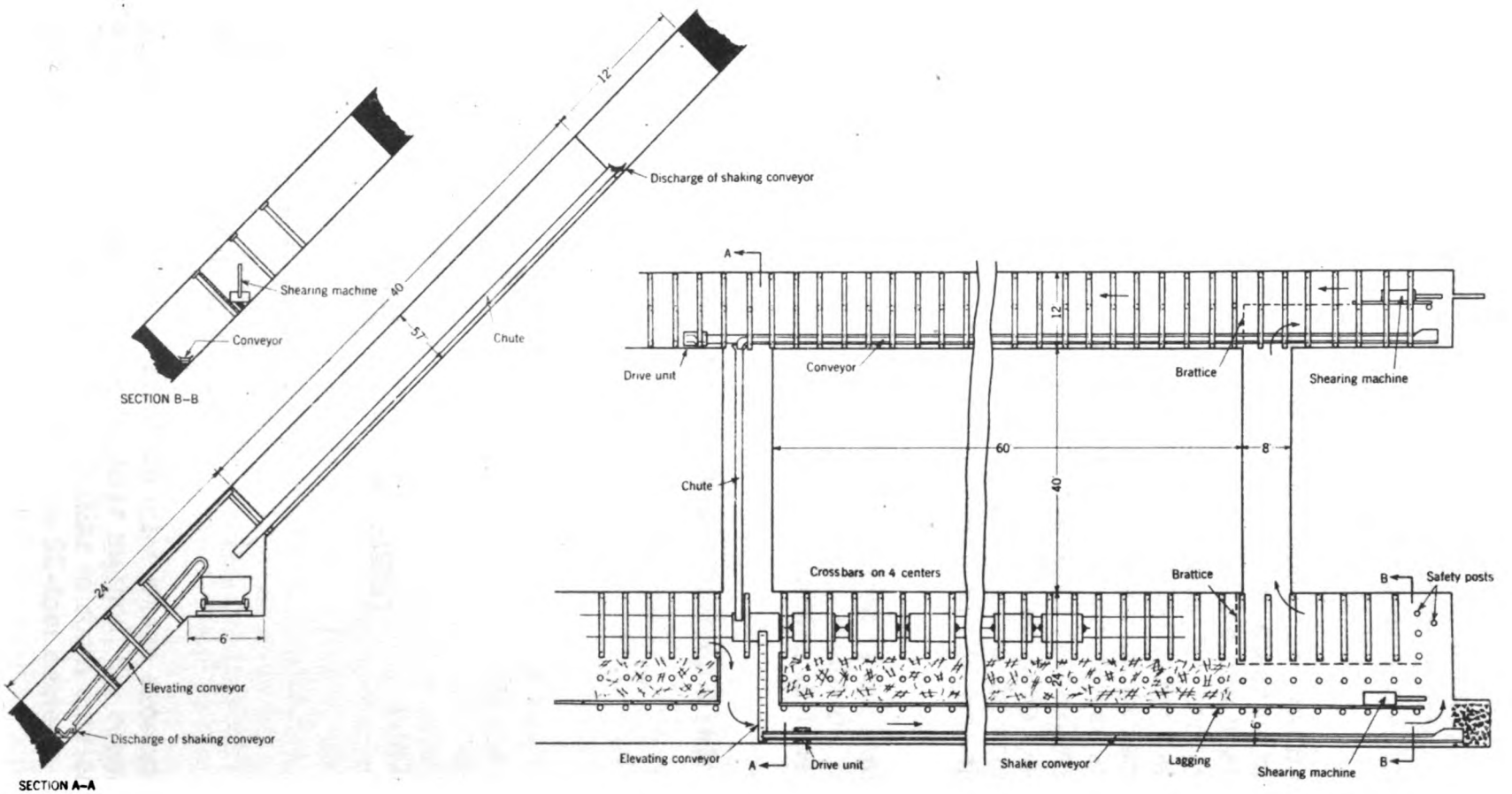

Figure 8.— Method of driving entries at mine 41.

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up the dip of the bed and discharges it into cars on the haulageway. When the heading has advanced approximately 300 feet, this elevating conveyor is pulled onto the track and skidded to the new location near the face and erected. It requires about four man-shifts to move from one site to another.

Because of the steep dip of the bed in these entries, shortwall cutting machines are considered to be dangerous; a special-type shearing machine rests on an adjustable mounting that maintains the machine in a horizontal position, and this mounting rests against the lagging along the conveyorway. The shear cut is 7 feet deep. One or two holes are drilled in the lower portion of the face near the rib by means of a portable electric or compressed-air auger drill. These holes are charged with permissible explosives and fired electrically. The loading pan of the conveyor is advanced manually into the broken coal, and after the coal from this part of the cut has been loaded, additional holes are drilled in the face, and the coal is blasted to the open end of the face. Little shoveling is required, as the broken coal slides to the conveyor pan.

The development of the air course is similar to that of the haulageway, except that the coal is discharged from the conveyor to a chute and passes by gravity to cars on the haulageway. (See fig. 8.) No brushing is done in the airway.

The men usually assigned during three shifts to develop a pair of entries where an elevating conveyor is used are as follows:

1	unit foreman
4	loaders
2	cutting-machine runners
2	cutting-machine helpers
2	face timbermen
1	conveyor runner
1	motorman
13	men per shift (26 men for two shifts)
3	brushers
2	permanent timbermen
5	men on one shift only
31	men per 24-hour period

Room development. - In the sections of the mine where excessive dips occur, the coal is extracted by the room-and-pillar method, the rooms being driven on the strike of the coal bed. A plane, similar to room entries, comprising manway and air course each 22 feet wide on 52-foot centers, is driven

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from the counter of the lower entry to the haulageway of the entry above. A ladderway, chute, and 12-inch-gage material track are constructed in the manway. (See fig. 9.) Rooms are turned from the manway compartment along the strike of the bed on 65-foot centers. These rooms are driven 35 feet wide and approximately 275 feet deep. Crosscuts between rooms are on 60-foot centers. (See fig. 9.)

Extraction of a panel is started in the chain pillar of the top entry. A shaking conveyor is erected on the high side of the working place adjacent to the pillar. Successive diagonal slices are taken off the pillars by blasting to the open side. Blasting is resorted to only when the load of the overlying strata fails to break the coal. The coal usually breaks to the cleats in the bed and flows by gravity to the loading pan of the conveyor. Only a minimum amount of shoveling is necessary. The conveyor has an overdrive, and the coal passes over the drive, is discharged into the chute, and passes into cars on the haulage entry.

Usually three rooms are worked simultaneously off an inclined plane - two on the advance and one on the retreat. A conveyor is erected along the lower rib of the room during the advance of the place. Conveyor pans are laid along the upper side of the room and serve as a materialway during the driving of the room. A small rubber-tired truck is operated in this pan line. This conveyor is used later when the room pillars are extracted.

Each working place is timbered with two parallel sets of timbers, as shown in figure 9. Temporary sets are used between the permanent timbers and the face.

A cut 6 feet deep and 8 feet wide is made in the bottom of the coal bed with a shortwall cutting machine, beginning at a point approximately 5 feet from the lower side of the place. It is considered unsafe to cut the entire face in these steep-pitch workings. Where the dip of the bed is as great as 45°, a shearing machine is used as it is in cutting the face in entries. The face is drilled with compressed-air, auger-type drills and blasted electrically with permissible explosives. The loading pan of the conveyor is advanced into the broken coal, and after this cut has been loaded, the remainder of the face is mined toward the open end. Very little blasting is necessary to dislodge the coal, as the roof action tends to break the coal to the vertical cleats in the bed. The face is kept at right angles to the direction of the room. A plank deflector is laid between the face and the timbers to guide the coal to the loading pan of the conveyor. Only a minimum of shoveling is necessary, as the greater part of the coal flows by gravity to the conveyor.

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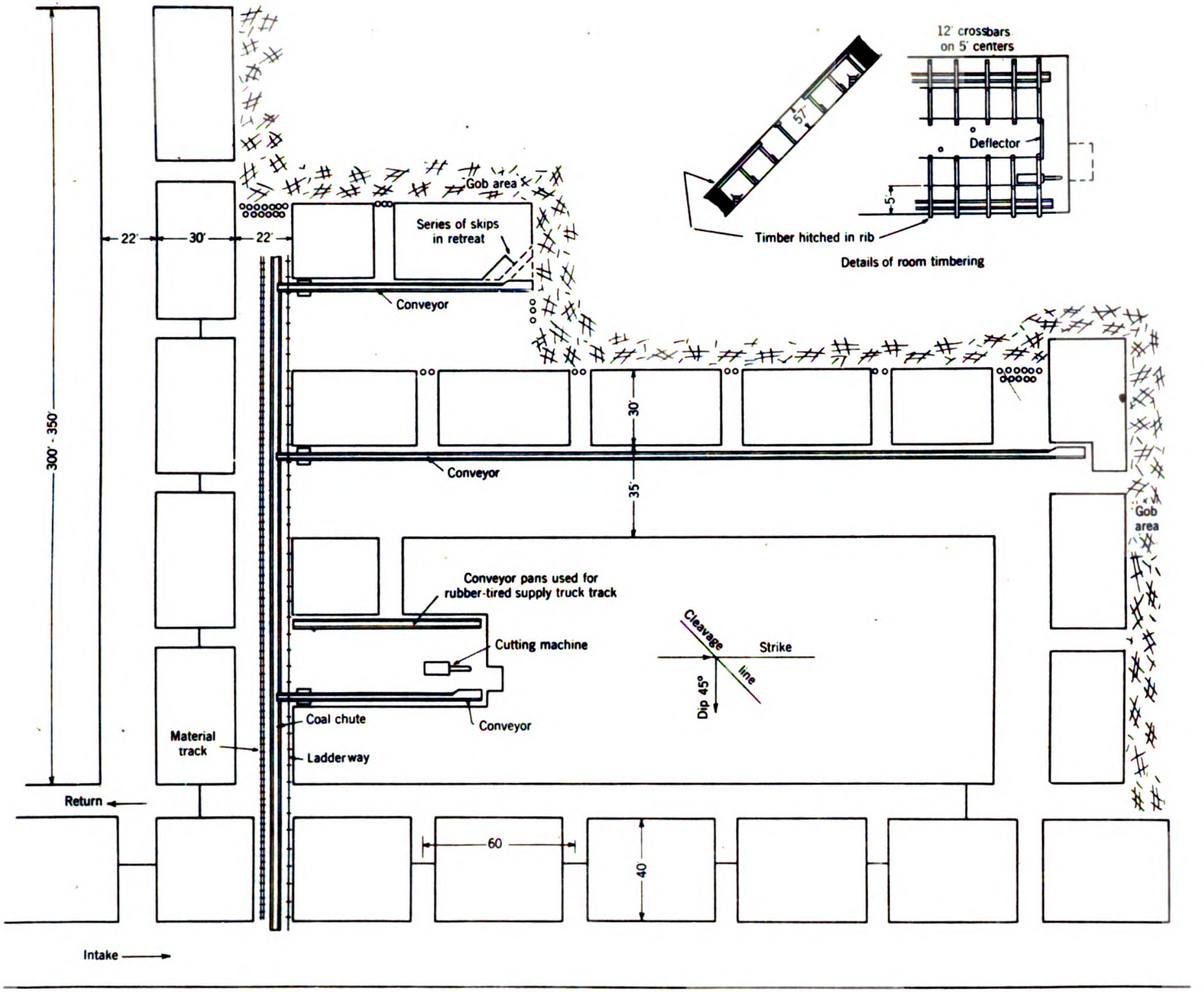

Figure 9.— Method of room-and-pillar mining on steep pitches at mine 41.

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When the room has been advanced to its depth, the lower conveyor is removed to a new location in the panel, and mining of pillars along the upper conveyor is begun. Owing to the dip of the bed, the weight of the overburden usually is thrown upon the lower side of the rooms and causes it to cave. The method used in extracting these room pillars is similar to that used in mining the entry chain pillars.

Each plane is equipped with a small electric hoist for raising timber and supplies to the working places in the panel.

A three-man crew is usually used in advancing a room, and two men generally extract the pillars. These men do all the work incident to mining the coal.

The coal is loaded into cars having an average capacity of 1.2 tons. Electric trolley locomotives transport a trip of eight cars from the loading point to the slope sidetracks. An 800-horsepower electric hoist transports the tirps up the slope to the surface.

Ventilation

The mine is ventilated by means of an electrically driven, 70- by 96-inch, double-inlet, centrifugal fan operated exhausting. All haulageways are on the intake of the ventilating system, and permanent stoppings are constructed of concrete.

Rock-dusting

All entries and working places are rock-dusted with an apparatus similar to that used in mine 40.

Classification of employees (24-hour period)

Classification	Rooms and pillars shifts			Development shifts			Grand total	Employees on mechanized units, percent
	Day	Night	Total	Day	Night	Total		
Underground employees:								
Loaders and duckbill men	17	17	34	9	6	15	49	47.1
Machinemen	2	2	4	4	4	8	12	11.5
Conveyor runners	1	1	2	3	3	6	8	7.7
Timbermen	7	7	14	5	5	10	24	23.1
Motormen	-	-	-	1	1	2	2	1.9
Foremen	2	2	4	3	2	5	9	8.7
Total employees chargeable to mechanized units	29	29	58	25	21	46	104	100.0

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up the dip of the bed and discharges it into cars on the haulageway. When the heading has advanced approximately 300 feet, this elevating conveyor is pulled onto the track and skidded to the new location near the face and erected. It requires about four man-shifts to move from one site to another.

Because of the steep dip of the bed in these entries, shortwall cutting machines are considered to be dangerous; a special-type shearing machine rests on an adjustable mounting that maintains the machine in a horizontal position, and this mounting rests against the lagging along the conveyorway. The shear cut is 7 feet deep. One or two holes are drilled in the lower portion of the face near the rib by means of a portable electric or compressed-air auger drill. These holes are charged with permissible explosives and fired electrically. The loading pan of the conveyor is advanced manually into the broken coal, and after the coal from this part of the cut has been loaded, additional holes are drilled in the face, and the coal is blasted to the open end of the face. Little shoveling is required, as the broken coal slides to the conveyor pan.

The development of the air course is similar to that of the haulageway, except that the coal is discharged from the conveyor to a chute and passes by gravity to cars on the haulageway. (See fig. 8.) No brushing is done in the airway.

The men usually assigned during three shifts to develop a pair of entries where an elevating conveyor is used are as follows:

1	unit foreman
4	loaders
2	cutting-machine runners
2	cutting-machine helpers
2	face timbermen
1	conveyor runner
1	motorman
13	men per shift (26 men for two shifts)
3	brushers
2	permanent timbermen
5	men on one shift only
31	men per 24-hour period

Room development. - In the sections of the mine where excessive dips occur, the coal is extracted by the room-and-pillar method, the rooms being driven on the strike of the coal bed. A plane, similar to room entries, comprising manway and air course each 22 feet wide on 52-foot centers, is driven

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Detail of work other than at face:

	Percent of time
Moving conveyors	1 60
Repairing conveyor lines	1.71
Rock dusting	.38
Brushing	3.75
Laying track	1.82
Permanent timbering	1.17
	10.43

Production during period, raw coal, tons	12,160	
Production from development, percent	35	
Production from rooms and pillars, percent	65	
Average production per man per shift, development, tons		5.35
Average production per man per shift, rooms and pillars, tons		8.66
Average production per man per shift, tons		7.12

Summary for average working day:

Percent of mine mechanized		100
Average daily production, raw coal, tons		850
Conveyor units		15
Conveyor shifts per day		29
Conveyor shifts per day, room-and-pillar	14	
Conveyor shifts per day, development	15	
Average number of men per unit per shift		3.60
Average number of men per unit per shift, room-and-pillar	4.15	
Average number of men per unit per shift, development	3.06	
Man-shifts per day on mechanized units		104
Man-shifts per day on mechanized units, room-and-pillar	58	
Man-shifts per day on mechanized units, development	46	
Average production per man per day on mechanized units, tons		8.17
Average production per man per day on mechanized units, room-and-pillar, tons	9.5	
Average production per man per day on mechanized units, development tons	6.5	
Total employees underground		139
Average production per man per day underground, tons		6.11
Total employees, surface and underground, chargeable to mechanized production		167
Average production per man per day, tons		5.1

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Mine 42

Production of this mine comes from mechanized sections in which the coal is hand-loaded onto chain conveyors. The average daily output is 1,510 tons in three working shifts.

The coal bed averages 30 inches in thickness, and the coal is soft and friable. The roof is shale and sandstone, and the stratum under the bed is hard, sandy clay. The surface is very rugged and the cover, which averages 650 feet, in places attains a thickness of 1,200 feet.

Mining Method

The mine is opened by two slopes and an air shaft. One slope, which is used for the transportation of men and material, is 330 feet long on a 26° pitch. The other slope contains a 42-inch belt conveyor for transporting coal and rock and is 530 feet long on an 18° pitch. The room-and-pillar system of mining is used, and the mine is developed by multiple main entries in sets of five and six headings. One set of main entries is driven north, and the other set is driven east. The block of coal between these main entries is developed by secondary main entries in sets of four headings on approximately 3,600-foot centers. Pairs of room entries are driven 1,800 feet long from these secondary entries on about 350-foot centers. Two hundred and fifty-foot barrier pillars are left to protect main and secondary entries.

All entries are driven 20 feet wide on 70-foot centers with the exception of the haulage entry, which is driven 14 feet wide, and brushed full width in the bottom. Crosscuts in main entries are driven 16 feet wide on 300- to 350-foot centers. Crosscuts in secondary entries are turned opposite the room entries.

The sets of entries are developed in pairs by advancing them a distance of 600 to 650 feet, two room conveyors being used in each entry. Then the conveyors are moved to the adjoining two entries, and the cycle is continued until all six of the entries have been advanced the required distance. (See fig. 10,A.) The haulage entry and the adjacent entry are usually driven first; and while the other entries in the set are being advanced, the bottom of the haulage entry is brushed on grade to provide a minimum clearance of 6 feet above the rail. The brushing is usually completed by the time the other entries have been advanced 600 to 650 feet. The bottom is drilled with compressed-air drills and blasted with 40-percent ammonium dynamite fired electrically. The rock is loaded into mine cars by a track-mounted, self-propelled scraper loader. Two sets of main entries were being driven at the time the mine was visited, one working single-shift and the other triple-shift. Equipment used for

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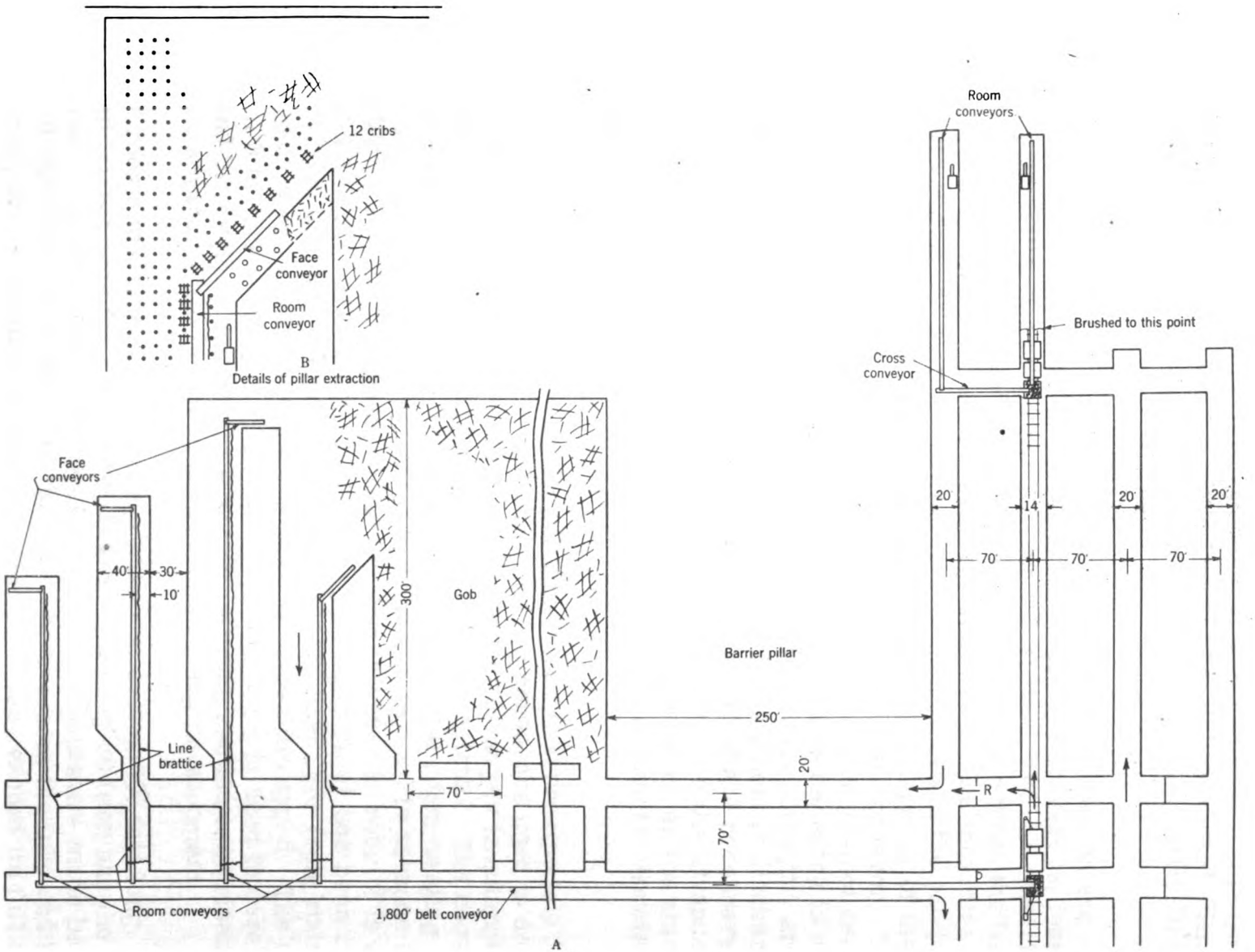

Figure 10.—Method of mining at mine 42.

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driving a set of main or secondary entries comprises four room conveyors (two for each entry of a pair) and one cross conveyor. A crew of 9 men (6 facemen, 1 car trimmer, 1 oiler and supply man, and 1 foreman) performs all the work necessary to mine the coal - timbering, cutting, loading, drilling, blasting, and setting conveyors. An entry crew mines approximately 30 tons of coal per shift.

Equipment for driving a pair of room entries, driving rooms, and extracting the pillars comprises four room conveyors, four face conveyors, four mining machines, four drills, one belt conveyor, one car spotter, and one electric hoist for moving conveyors. The entries are driven the distance across the barrier pillar, 250 feet, by means of chain conveyors, which discharge into mine cars on the haulage entry. A 26-inch belt conveyor is then placed in the entry parallel to the one from which rooms are to be turned, and the development of the two entries is continued with two room conveyors and one cross conveyor. The crosscuts between entries are turned opposite room necks on 70-foot centers and driven halfway from each entry. Rooms are necked as the entry is advanced. Face chain conveyors, which discharge onto the entry chain conveyor, are used in crosscuts and room necks. The coal from this development is discharged onto the belt conveyor. The roof of the belt entry is brushed where necessary to permit installation of the conveyor. The coal is extracted on the advance, and the first room is turned adjacent to the barrier pillar as soon as the entry has been advanced far enough to permit the installation of equipment; likewise, room No. 2 is started.

Development of the pair of entries is continued for approximately 210 feet, or three room lengths beyond No. 1 room. The two conveyors used to develop the entries are then placed in rooms 3 and 4, the belt conveyor is extended, and entry development is stopped until room 1 has been completed. The conveyor from room 1 is then used to advance the two entries. The room heading is driven approximately 280 feet, and then the conveyor is used to advance the belt heading. While this entry is being developed, the conveyor in room 2 is used for extracting the pillar between rooms 1 and 2. When this pillar has been removed, the entries have usually been advanced 280 feet. The conveyor from room 2 is then moved to room 5, and the entry conveyor is placed in room 6. The conveyor from room 3 is moved to room 7, the conveyor of room 4 is used to develop the entries, and the cycle is continued. A normal working section comprises three rooms (two advancing and one retreating) and the entry development.

The rooms are turned on 70-foot centers and driven 300 feet long. They are necked 20 feet wide for three cuts, or approximately 20 feet, and the width is increased to about 40 feet. (See fig. 10,A.) No crosscuts are made between rooms, and the solid pillar, 30 feet wide, is extracted from the inby end by the open-end method. Extraction begins when the room has reached its full depth. (See fig. 10,B.)

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In extracting the pillar between rooms, a cut-over is made in the pillar at the inby end of the room. The end of the pillar is then cut, and extraction proceeds by making repeated cuts on this open end. The cuts are so made that the face of the pillar is at an angle of about 45° to the room line. The room is carefully timbered on the advance by using posts set on 4-foot centers. During pillar removal the face is protected by 12 cribs, as shown in figure 10,B These cribs are moved as the face of the pillar retreats.

The cycle of mining is timber and crib, cut, move up conveyors, blast, and load. In advancing the room, four shot holes, each charged with 2-1/2 to 3 sticks of permissible explosive, are enough to bring down the coal; in pillar removal only occasional shots are needed An average room section crew is as follows:

14	facemen, who timber, cut, move conveyors, drill, blast, and load.
1	ventilation man
1	oiler
1	supply man
1	belt-maintenance man
1	car trimmer
1	foreman

The coal from a section is discharged from the conveyor belt into 3 6-ton mine cars, which are transported to the slope bottom in trips of 30 cars by two 6-ton trolley locomotives (a locomotive on each end of the trip). The cars are steel, solid-end type and are dumped singly, without uncoupling, into a rotary dump.

The main belt and room conveyors are reversed to move supplies from the haulageway to the faces.

Ventilation for the mine is furnished by a 7-foot propeller-type fan operating exhausting. The haulageways and rooms of the section are the intake in the ventilating system. The conveyor belt usually is in the return air course The air current is carried to the working faces by line brattices.

Water is used on the cutter bar of mining machines, and the faces are sprinkled with water after the coal is blasted and during loading. In addition, the outby portion of the room is sprinkled regularly.

Atomizing sprays are placed at intervals along the haulageways and belt entries to allay dust. Two hundred of these sprays were in use when the mine was visited.

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Electric power, which is supplied to the mine at 60-cycle, 3-phase, alternating current, is converted to 250-volt direct current by motor-generator sets for mine use.

Classification of employees

Classification	First shift	Second shift	Third shift	Total
Underground:				
3-room-and-pillar sections:				
Facemen	42	42	42	126
Ventilation men	3	3	3	9
Oilers	3	3	3	9
Supply men	3	3	3	9
Car trimmers	3	3	3	9
Belt-maintenance men	3	3	3	9
Foremen	3	3	3	9
Development (two sets of entries):				
Facemen	12	6	6	24
Car trimmers	2	1	1	4
Oilers and supply men	2	1	1	4
Foremen	2	1	1	4
Total men on mechanized equipment	78	69	69	216
Other underground employees:				
Locomotive operators	2	2	2	6
Brakemen	2	2	2	6
Ventilation	4	1	1	6
Pumpers	1	1	1	3
Trackmen	2	-	-	2
Wireman	1	-	-	1
Electricians	2	1	1	4
Dumpers	1	1	-	2
Spraymen	2	1	1	4
Brushers	6	6	6	18
Foremen	1	1	1	3
Fireboss	1	1	-	2
Supply men	2	-	-	2
Total other underground employees	27	17	15	59
Total underground employees	105	86	84	275

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Classification	First shift	Second shift	Third shift	Total
Surface employees:				
Lampmen	1	1	1	3
Electrical repairmen	2	-	-	2
Car repairmen	2	-	-	2
Blacksmith	1	-	-	1
Truck drivers (rock disposal)	3	3	-	6
Tipplemen	10	14	-	24
Sand drier	1	-	-	1
Timekeeper	1	-	-	1
Office clerks	4	-	-	4
Supervision	2	-	-	2
Total surface employees	27	18	1	46
Total employees, surface and underground	132	104	85	321

Summary

Mechanization of mine, percent	100
Average daily production, tons	1,510
Conveyors:	
Development	4
Room-and-pillar	12
Conveyor shifts per day:	
Development	8
Room-and-pillar	36
Average number of men per conveyor per shift, development	4.5
Average number of men per conveyor per shift, room-and-pillar	5
Man-shifts per day on mechanized units	216
Average production per day per man on mechanized units, tons	7.0
Total employees underground	275
Average production per day per man underground, tons	5.49
Total number of employees	321
Average production per day per man employed, tons	4.70

Mine 43

The topography of the area is mountainous, and the coal bed outcrops high on the sides of valleys. The mine opening is a drift in the bed averaging 54 inches in thickness and containing a thin rash parting in the middle of the bed. The strata above and below the bed are sandy shales.

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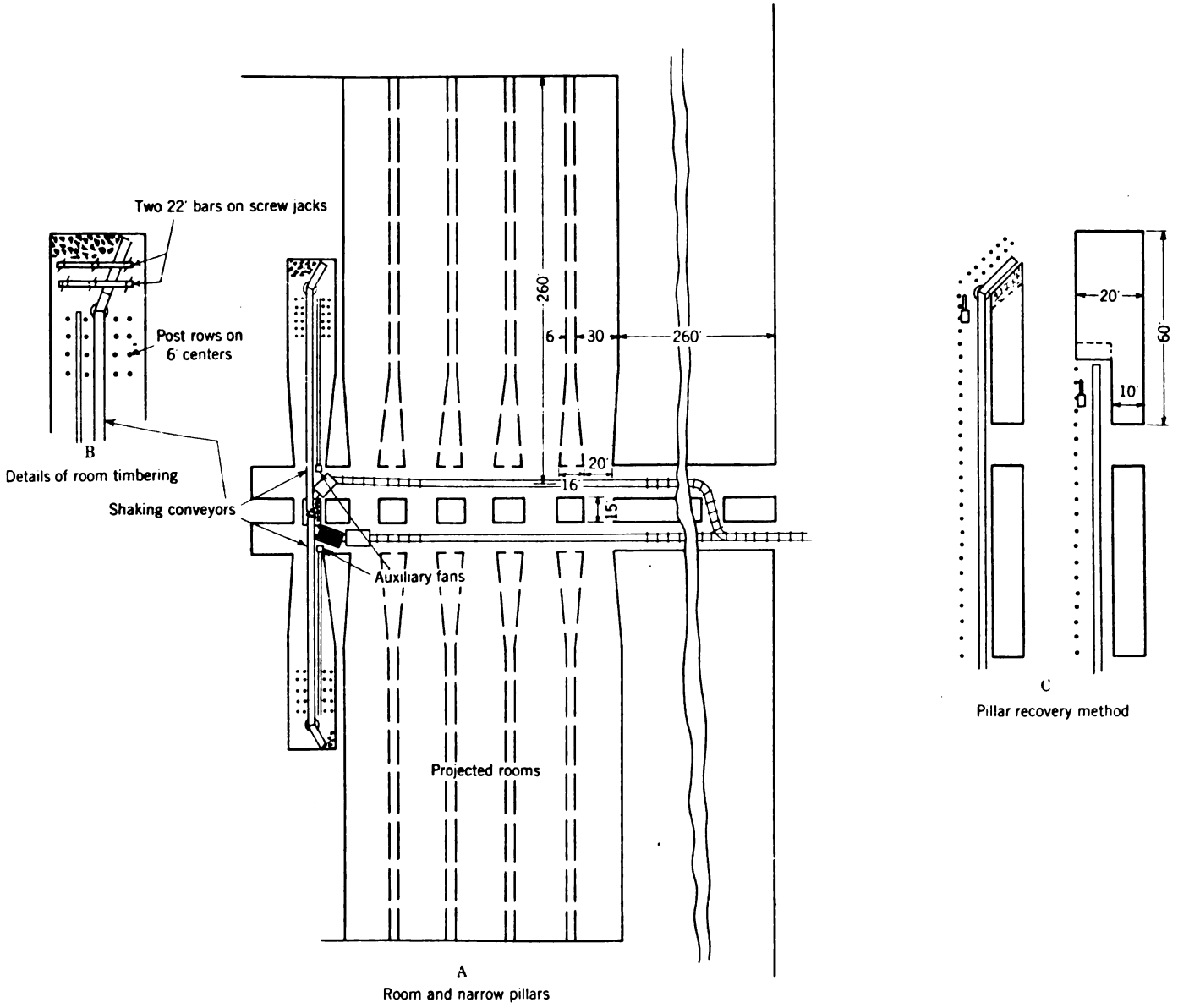

Figure 11.— Method of mining at mine 43.

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The mine is developed from main entries that traverse the property, and the workings are sectionalized. The room-and-pillar system of mining is followed. Room entries are turned right and left off cross entries at intervals of approximately 520 feet. Entries are driven 20 feet wide on 35-foot centers. Rooms are turned on 36-foot centers both to the right and left off the entries, and a 280-foot barrier pillar is left to protect the entry. Rooms are started 20 feet wide, and the necks are gradually widened for 60 feet to room width, 30 feet. Rooms are 260 feet long. No crosscuts are driven between rooms, and ventilation at each working face is supplied by a 2-1/2-horsepower blower fan equipped with 12-inch canvas tubing Crosscuts between entries are driven opposite each room neck. (See fig. 11,A.) Each working place has the following equipment:

1 shortwall cutting machine equipped with 6-1/2 or 7-foot cutter bar
1 shaking conveyor
1 portable, electric, auger-type drill

When the rooms are being developed, the shaking conveyors are equipped with self-loading heads. Coal from the extraction of pillars is loaded by hand onto the conveyors. A section comprises two conveyors in opposite rooms off the entries. The coal is discharged from the conveyors into cars on the entry or in the crosscut. The following men perform all the work necessary to getting out the coal in a section:

8 facemen (4 men to each conveyor)
1 timberman
1 hoistman
1 foreman
11

The four facemen are classified as follows:

1 conveyor-head operator
1 cutting-machine operator
2 general conveyor men

Each working place is timbered with rows of four posts, two rows on each side of the conveyor, and the rows are 6 feet apart. During loading operations two crossbars 22 feet long on 6-foot centers and each supported by three or four screw jacks protect the workmen at the face. Screw jacks are used, as they may be moved readily as required to permit changing the position of the loading head. After a cut of coal has been removed, permanent timbers are set. (See fig. 11,B.) The 6-foot pillar between rooms is not recovered. The pillars usually

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crush, and the rooms cave after the coal from 10 rooms has been extracted. Subsequent falls generally occur two rooms inby the first working room

A room is generally advanced its full distance, 230 feet, in 12 to 14 shifts, and one shift is usually required to remove two conveyors and set up the equipment in the next two rooms. Ten men do this work in one shift.

In the part of the mine where the coal had been extracted by hand-mining methods, pillars 20 feet wide by 60 feet long were left between rooms These pillars are being recovered by means of shaking conveyors. A place 10 feet wide is driven along the side of the pillar, and when this place has been driven the length of the room, successive cuts are made at 45° on retreat across the remaining 10 feet of the pillars. (See fig. 11,C.) This coal is hand-loaded onto shaking conveyors. The tons per man employed at the face on conveyors in this work averages approximately 3 tons less than in room work where conveyors with self-loading heads are used. The estimated recovery under the two mining methods averages 82 percent of the area of the bed

To prepare for blasting, four holes usually are drilled above the rash parting in a 30-foot place. The two side holes are approximately 18 inches from each rib The holes are charged with permissible explosive and fired electrically Approximately 10.75 tons of coal are produced per pound of explosive. The three holes from right to left are blasted successively, and this part of the coal is loaded. The fourth hole is then blasted, and while this coal is being loaded the right side of the face is cut. An example of the cycle of work performed by the men in a working place follows:

Man	Classification
A	Conveyor loading-head operator
B	Conveyor loading-head operator's helper
C	Conveyor loading-head operator's helper
D	Cutting-machine operator

D	Sumps cutting machine on right side of place
A and B	Load coal from fourth hole on left side of place.
C	Helps to remove coal from in front of conveyor
D	Starts cutting across face.
C	Goes to right side of room and begins to remove cuttings from cut.

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D	Cuts approximately three-fourths of face and then assists C to drill, load, and tamp three holes.
A and B	Complete loading coal from left side of room Release conveyor clamps and swivel jacks. Position of screw jacks is changed as required.
D	Uses rope of mining machine to pull loading head of conveyor into position on right side of place. The holes on right side of the room are blasted. Roof is examined and jacks are set for temporary support.
A and B	Begin loading coal.
C	Assists loading.
D	Completes cut across working place, and C cleans cuttings from undercut. Cutting machine is removed from the face, and the face is prepared for blasting by drilling and charging No. 4 hole.
C	Assists A and B in loading right portion of place.
D	Sets cutting bits and places machine in position for sumping in righ side of face
B, C, and D	Move crossbar to new position, and cycle is continued

The coal is discharged from conveyors into 1 45-ton-capacity end-dump cars. The trips, usually 20 cars, are moved at the loading point by an electric hoist, which is operated by the car trimmer Generally one gathering locomotive serves two sections. The trips are transported from the sections to a main-line parting and are hauled by a main-line trolley locomotive from this parting to the outside dumping station in trips of 40 cars. A safety drag is used on the end of main-line trips.

Classification of employees (24-hour period)

Classification	First shift	Second shift	Third shift	Total
Underground:				
5 sections of 11 men, solid work	55	55		
1 section of 11 men, pillar work	11	11	-	
2 sections of 8 men, clean-up	-	-	16	
3 gathering-locomotive crews	6	6	-	
1 gathering-locomotive crew	-	-	1	
Total men on mechanized units	72	72	17	161

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Classification	First shift	Second shift	Third shift	Total
Other underground employees:				
2 main-line locomotives	4	4	-	
Trackmen	3	-	-	
Bratticeman	1	-	-	
Pumper	1	-	-	
Wireman	1	-	-	
Supply men	2	-	-	
Mine foremen	1	1	-	
Total other underground employees	13	5	-	18
Total underground employees				179
Surface employees:				
Tipple and head house	13	12	-	
Shopmen and repairmen	10	-	-	
Laborers	2	-	-	
Total surface employees	25	12	-	37
Total employees, surface and underground				216

Summary

Mechanization of mine, percent	100
Average daily production, raw coal, tons	1,890
Conveyors	12
Conveyor-shifts per day	28
Tons per conveyor-shift	67.5
Man-shifts per day on mechanized units	161
Average number of men per unit per shift	5.75
Average production per man per day on mechanized units, tons	11.73
Total employees underground	179
Average production per man per day, underground, tons	10.56
Total employees, underground and surface	216
Average production per man per day, tons	8 75

Mine 44

The coal bed at this mine is variable in thickness, ranging from 40 to 72 inches. The stratum under the coal is hard fire clay, and that above the bed is a hard sandy shale. The thin coal areas are usually on wide plateaus, and the thick coal areas lie in broad, irregular valleys. Local dips, some as great as 13 percent, occur through the area. The surface over the bed is irregular and

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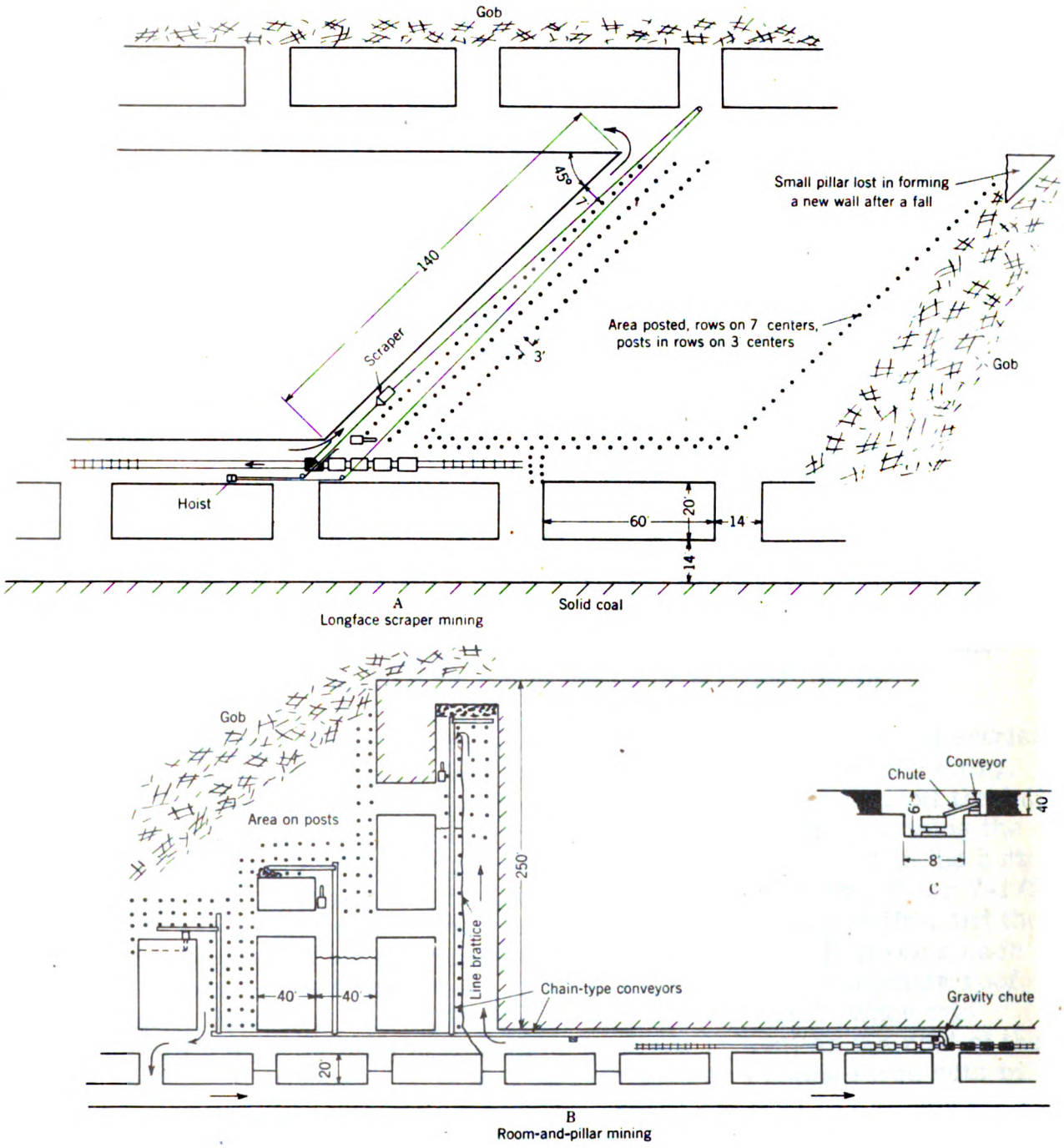

Figure 12.— Methods of mining at mine 44.

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mountainous, the depth of cover ranging from 200 to 1,100 feet. There appears to be no relation between bed and surface irregularities.

Mining Method

The mine is opened by two shafts - one serving men, supplies, and air and the other for hoisting coal. Main entries are driven to the boundaries, and the areas are developed and extraction is on a retreat system. Both the room-and-pillar system, with some modifications, and the long-face or wall system are used.

Main entries are driven in triplicate 14 feet wide on 50-foot centers. Cross entries are turned in pairs on 50-foot centers at approximately 2,000-foot intervals - the interval is not uniform. Room and wall entries are driven 14 feet wide on 34-foot centers, and the distance driven depends on the placement of cross entries.

Haulage entries are brushed 8 feet wide in the bottom to provide a minimum clearance of 5-1/2 feet above the rail; the top may be brushed where abrupt changes in grade are encountered. At the time the mine was visited, all mining was on retreat in barrier or entry pillars. Mechanical mining is done only in the thin areas where the coal averages 40 inches, scraper hoists are used on long faces, and conveyors are used in the room-and-pillar sections. (See fig. 12.) Mining operations are conducted on a two-shift basis.

Scraper loading. - The scraper wall extends between two pairs of entries 110 feet apart, and the wall is 140 feet long at an angle of 45° from the entry. (See fig. 12,A.) The wall is started either by taking successive cuts off the inby end of the block or by driving a pair of rooms through the block and using the outby rib of the outby room as the face of the wall. The coal is cut in the bottom of the bed by means of a shortwall mining machine equipped with a 7- or 7-1/2 foot cutter bar. Cutting and timbering are done between loading shifts, and the wall is advanced two cuts, or approximately 14 feet, per day. Following each cut, one row of posts on 3-foot centers is used to support the immediate roof. A wall is usually advanced 150 to 225 feet before a fall occurs. When this happens, normally only the inby half of the angle face is lost, as the roof of the outby portion is less stressed. The wall is reformed by making three cuts in the outby portion and then driving an opening through the coal to the inby entry, leaving a small pillar for protection. Eighteen holes are drilled per wall, and the coal is blasted by permissible explosives fired electrically.

The equipment used on a wall comprises one 3/4-ton scraper-loader, one shortwall mining machine, one portable electric drill, and one locomotive. The crew of men used to operate the equipment comprises:

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1	hoistman
1	bellman
2	facemen
1	brakeman
2	machinemen and timbermen
1/2	foreman (1 foreman for two sections)
7-1/2	

Conveyor mining. - Where conveyors are used, a unit set-up consists of three rooms in which three face conveyors, three room conveyors, and two conveyors in series for transportation on the entry are used. Normally one room is on advance and two on retreat. When the pillar of the inby room has been extracted, the equipment of that room is used to drive the next new room. The rooms are driven 40 feet wide on 80-foot centers (see fig. 12,B), and the pillars are extracted by the open-end method. Rooms are timbered with four or more rows of posts when advancing, and when pillars are being extracted one row of posts is set in the open area for each cut. The posts are set as close to the face as possible, leaving only enough space to permit cutting and placement of the face conveyor. The coal is hand-loaded onto the face conveyors, which discharge it onto the room conveyors. The coal is transported by these conveyors to the entry conveyors and is discharged into mine cars. The crew performing the work of cutting, drilling, blasting, loading, and timbering in a section of three rooms is classified as follows:

13	facemen
1	bratticeman
1	car trimmer
1/2	foreman (1 foreman for two sections)
15-1/2	

Classification of employees (24 hour period)

Classification	Units	First shift	Second shift	Total
Underground:				
Scraper wallmen	1	6	6	
	1	4	4	
		10	10	20
Cutters and timbermen	1	2	2	
	1	2	2	
		4	4	8
Foreman		1	1	2
Total, scrapers	2			30

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Classification	Units	First shift	Second shift	Total
Underground: (Cont'd.)				
Conveyor section:				
Facemen	2	26	26	52
Car trimmer		2	2	4
Bratticemen		2	2	4
Foremen		1	1	2
Total on conveyors	2			62
Total on mechanized units				92
Other underground employees:				
Motormen and brakemen		4	4	8
Pumpers		1	1/2	1-1/2
Electricians		1	1	2
Trackmen		2	-	2
Wiremen		1	-	1
Laborers (general)		2	1/2	2-1/2
Supervision (mine foreman, safety engineer, assistant foreman, and fireboss)		3	1	4
Total underground				113
Surface				36
Total chargeable to mechanized production				149

Summary

Mechanization of mine, percent	54.1
Average daily mechanized production, tons:	
Walls	400
Conveyors	900
Scraper units	2
Conveyor units	2
Scraper shifts per day	4
Conveyor unit shifts per day	4
Average number of men per unit per shift, scraper	7.5
Average number of men per unit per shift, conveyors	15.5
Man-shifts per day on mechanized units	92
Average production per day per man on mechanized units, tons	14.13
Walls 13.33	
Conveyors 14.45	
Total employees underground chargeable to mechanization	113
Average production per day per man underground chargeable to mechanized production, tons	11.5

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Total employees, surface and underground, chargeable to mechanized production 149
Average production per day per man employed chargeable to mechanized production, tons 8.7

Mine 45

The mine is opened by three shafts to a 34-inch bed of high-quality coal that is fragile, and a large percentage of the production is small sizes. The bed contains no definite cleats. The stratum beneath the bed is hard shale containing numerous horsebacks of varying width, which exte nd into the bed. The roof is a hard, sandy shale. The mine is operated two shifts daily, and 53 percent of the production (1,120 tons) is hand-loaded onto conveyors.

Mining Method

The room-and-pillar system of mining is used. The mine is developed by driving main entries in triplicate and cross entries in pairs; room entries are turned in pairs from the cross entries. Cross entries are turned on about 2,200-foot centers and room entries on approximately 325-foot centers. All entries are driven 13 feet wide on 60-foot centers, and the haulage entries are brushed in the top to provide 5-1/2 feet clearance. Barrier pillars 250 feet wide are left to protect cross and main entries.

After room entries have been driven to a predetermined limit, rooms are turned on 75-foot centers and are driven 40 feet wide. Rooms are started at the inby end of the entry, and extraction is on retreat. Rooms are normally worked in sets of two, the pillar of the inby room on retreat and the outby room advancing. (See fig. 13,A.) Crosscuts are driven 14 feet wide on 80-foot centers. Rooms are timbered with 10 rows of posts on approximately 4-foot centers. Additional posts are used at the face as required. The pillar between rooms is extracted by making successive cuts across the inby end, and the roof is supported by two rows of six wooden cribs. As each successive cut is removed, the back row of cribs is advanced to a new position within approximately 7 feet of the face. (See fig. 13,B.)

A set-up for two rooms comprises the following equipment, all of which is the permissible type:

3 300-foot room chain conveyors
2 26-foot face chain conveyors
1 elevating conveyor
2 electric drills
2 7-1/2-foot bar, shortwall mining machine
1 blower fan and tubing1/
1 junction box

1/ Since study was made, the use of the blower fan has been discontinued.

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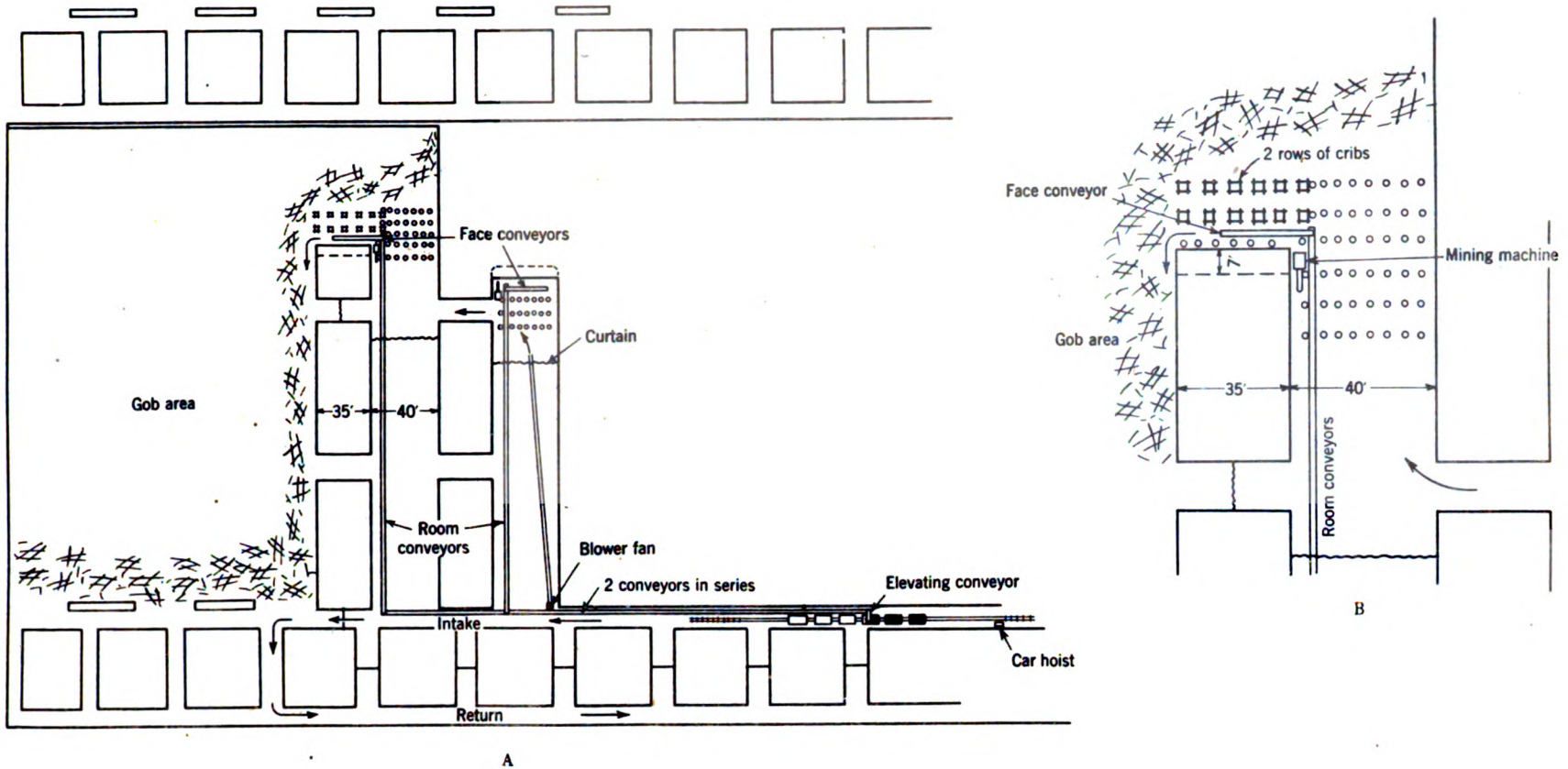

Figure 13.— Method of mining at mine 45.

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The cut is made in the bottom of the bed. Six holes are drilled in the face of advancing rooms for blasting, and each hole is charged with two sticks of permissible explosive; three holes are fired simultaneously. Only an occasional shot is required to bring down the coal in pillar extraction.

A normal crew for one conveyor section, two rooms, comprises eight men, one car trimmer, and one section foreman. These men do all of the work necessary to mine and deliver the coal to cars on the entry. Six conveyor sections were in operation at the time the mine was visited.

The coal from each room is loaded by hand onto a face conveyor, which discharges it onto a chain-type room conveyor. The room conveyor transports the coal to a cross conveyor on the entry. This cross conveyor transports it from the two rooms to an elevating conveyor, which discharges the coal into mine cars. The car-loading station is situated outby the working rooms. (See fig. 13,A.) The cars, each of which has a capacity of 2.45 tons, are loaded in trips of 12.

Alternating current is supplied to the mine and is converted to 550-volt direct current for mine use by a mercury arc rectifier. Electrical power is supplied to each conveyor section through a junction box. All electrical circuits were on intake air currents, and the mine is rock-dusted.

The mine fan is operated exhausting and circulates 140,000 cubic feet of air per minute; the ventilating circuit in the mine comprises four splits.

The high percentage of extraction obtained (approximately 95 percent) is attributed to rapid extraction of pillars and the solid coal immediately adjacent to the rib lines.

Classification of employees (24-hour period)

	Day	Night	Total
Underground:			
Conveyor sections (6):			
Facemen	48	48	96
Section foremen	6	6	12
Car trimmers	6	6	12
Motormen and brakemen	4	4	8
Total men on mechanized units	64	64	128

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	Day	Night	Total
Other underground[1]:			
Maintenance men	2	2	4
Trackmen	2	2	4
Main-line motormen	2	1	3
Main-line brakemen	2	1	3
Ventilation men	1	-	1
Pumpmen	1	-	1
Wiremen	1	-	1
Bottom men	2	-	2
Maintenance foremen	1/2	-	1/2
Foreman	1	-	1
Total other underground	14-1/2	6	20-1/2
Total underground	78-1/2	70	148-1/2
Surface[1]:			
Tipple	14	-	14
Hoistman	1-1/2	-	1-1/2
Lampman	1	-	1
Stemming man	1	-	1
Blacksmith	-	1	1
Car repairmen	3	2	5
Foreman	1/2	-	1/2
Superintendent	1/2	-	1/2
Total surface	21-1/2	3	24-1/2
Total employees	100	73	173

1/ Number of men charged is based upon percentage of mechanized production.

Summary

Mechanization of mine, percent	53
Average daily production from mechanized units, tons	1,120
Conveyor sections	6
Conveyor units	12
Conveyor units, shifts per day	24
Average number of men per unit per shift	5.33
Man shifts per day on mechanized units	128
Average production per man per day on mechanized units, tons	8.75
Total number of employees underground chargeable to mechanized units	148-1/2
Average production per man per day underground, tons	7.54
Total number of employees, surface and underground	173
Average production per day per man employed, tons	7.47

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GENERAL DISCUSSION

No categorical answer can be given to the questions stated in the introduction, but from the investigations made thus far the following answers are presented:

1. A common error in equipping a mine for mechanical loading is the failure to study natural conditions and choose the type of equipment suited to them. In many instances no change was made in the design of the mine or method of extraction. Introduction of loading equipment, especially mobile loading machines, usually requires some change in mine design and method of extracting pillars, particularly where the roof is fragile. Where no thought has been given this problem, small pillars and stumps that normally were removed by hand-loading methods using close timbering have been lost, and recovery has declined.

Credit should be given to those operators who first tried the various types of equipment and passed on their experience. Successful transition was usually made after considerable study of bed and roof conditions.

2. To the question, "Can the method of extracting pillars by hand be adapted to mechanical loading?" no positive answer can be given. Hand-loading methods usually are unsuited for mechanical loading devices, particularly mobile loading machines. The most successful hand-mining method for pillar removal is the pocket and wing in rectangular blocks. Close timbering is required to recover the wing. This system has not been successful with mechanical loading devices because the area is restricted by timbering. Pillar extraction with mechanical devices however, has been successful with the open-end or thin-shell systems, because the rate of extraction is rapid. The time element in hand-loading does not favor the open-end method.

3. Past experience indicates that less tonnage per day per mobile loading machine is produced on pillar work than where pillars are not recovered. The opposite is usually true where conveyors or scrapers are used.

4. Extraction of pillars with machines introduces additional hazards. Motion and noise of machines and transporting equipment and, in some instances, the liberation of additional gas due to rapid exposure of wall surfaces, are also dangers. Many hazards are obviated or decreased where mechanical mining is practiced. Roof movement is delayed by rapid extraction; concentration of workers permits closer supervision, and ventilation can be controlled more readily.

Table 2 summarizes performance at mines where mobile loading machines are used.

Table 3 summarizes performance at mines where conveyors are used.

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TABLE 2. - Summary of performance of mobile loaders

	Mine		
	35	36	
		A	B
1. Description of mechanization:			
a. Cutting machines, type	Track-mounted and shortwall	Track-mounted	Track-mounted
b. Loading machines, type	Crawler, mobile	1 crawler, mobile 5 track, mobile	1 crawler, mobile 3 track-mounted mobile
c. Machine loading	Mine cars	Mine cars	Mine cars
2. Location of mine	Pennsylvania	Pennsylvania	Pennsylvania
3. Mechanization of mine, percent	100	100	100
4. Average daily production, tons	3,300	3,500	2,100
5. Thickness and dip of bed	64 inches, level	80 inches mined, 108 inches rolling, 13 percent max.	80 inches mined, 108 inches rolling
6. Number and hours of shift in mine	2 - 7 hr.	2 - 7 hr.	2 - 7 hr.
7. Number and hours of shift in tipple	1 - 7 hr.	2 - 7 hr.	1 - 7 hr.
8. Loading machines	13	6	4
9. Loading-machine shifts per day	26	12	8
10. Average production per loading machine per shift, tons	126	292	262
11. Average number of men per unit per shift	13.75	19	19
12. Man-shifts per day on mechanized units	358	228	152
13. Average production per man per day on mechanized units, tons	9.20	15.4	13.8
14. Total number of employees underground	551	318	194
15. Average production per day per man underground, tons	5.98	11.0	10.8
16. Total number of employees, surface and underground	646	366	229
17. Average production per day per man employed, tons	5.10	9.5	9.2
18. Average production of coal per pound of explosives, tons	3.85	5.8	-
19. Average production of coal per prop, tons	6.6	1/10	11.1
20. Total power consumed per ton of coal, kw.-hr	10.1	4.0	-
21. Size of mine car, tons	2.75	3.2 and 3.8	2.8
22. Estimated recovery, percent	80	82	82

1/ 28 tons per crossbar.

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TABLE 3. - Summary of performance of conveyors

	Mine 40	Mine 41	Mine 42
nization:			
es, type	Shortwall	Shearing	Shortwall
e	Shaking conveyor	Shaking conveyor	Chain and belt conveyors
g	Mine cars	Mine cars	Mine cars
	Washington	Washington	West Virginia
e, percent	100	100	100
tion from mechanized units, tons	1,605 (R & P 1,075, Dev. 530)	850 (R & P 550, Dev. 300)	1,510 (R & P 1,390, Dev. 120)
bed	54 inches - 5° to 23°	54 inches - Up to 45°	30 inches - Level
shift in mine	See text.	See text.	3 - 7 hr.
shift in tipple	1 - 7 hr.	1 - 7 hr.	2 - 7 hr.

	Mine	R & P	Dev.	Mine	R & P	Dev.	Mine	R & P	Dev.
	19	10	9	15	7	8	16	12	4
day	28	15	13	29	14	15	44	14	8
er conveyor per shift, tons	57	72	41	29	39	20	34	39	15
n per unit per shift	5.42	6.26	4.46	3.6	4.1	3.1	4.9	5	4.5
n mechanized units	152	94	58	104	58	46	216	180	36
er man per day on mechanized units,	10.56	11.43	9.13	8.17	9.5	6.5	7.0	7.7	3.34
oyees underground	197			139			275		
er day per man, underground, tons	8.15			6.11			5.49		
oyees, surface and underground	235			167			321		
er day per man employed, tons	6.82			5.1			4.70		
f coal per pound of explosives,	1/5.1			1/12.6			-		
f coal per prop, tons	5.9			3.8			-		
per ton of coal, kw.-hr	10.2			10.3			-		
ns	1.2			1.2			3.6		
percent	97			97			90		

d brushing.

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rformance of mobile loaders (Cont'd.)

	Mine			
	37	38	39	
			A	B
..	Track-mounted	Track-mounted	Track-mounted	Track-mounted
..	Track-mounted, mobile	Crawler-mounted, mobile	do.	do.
..	Mine cars	Mine cars	Mine cars	Mine cars
..	Kentucky	Virginia	West Virginia	West Virginia
..	100	76	100	100
..	1,320	3,604	4,200	950
..	60 to 84 inches, level	54 inches, level	108 inches	45 inches
..	See text.	2 - 7 hr.	2 - 7 hr.	2 - 7 hr.
..	2 - 7 hr.	2 - 7 hr.	2 - 7 hr.	2 - 7 hr.
..	3	13	6	2
..	7	28	12	5
s.	188	129	350	190
..	18	13.35	18	17
..	126	374	216	85
s,				
..	10.50	9.64	19.4	11.2
..	160	432	304	117
..	8.25	8.34	13.8	8.1
..	197	468	366.8	131.2
..	6.7	7.70	11.4	7.2
..	Cardox	9.44	-	-
..	2/8.43	3/6.29	-	-
..	-	-	-	-
..	2.7	4.0	3.9	2.4
..	92	95	95	95

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TABLE 3. - Summary of performance of conveyors (Cont'd.)

	Mine 43	Mine 44	Mine 45
1. Description of mechanization:			
a. Cutting machines, type	Shortwall	Shortwall	Shortwall
b. Conveyors, type	Shaking conveyors	Chain conveyors and scrapers	Chain conveyors
c. Machine loading	Mine cars	Mine cars	Mine cars
2. Location of mine	Kentucky	West Virginia	West Virginia
3. Mechanization of mine, percent	100	54.1	53
4. Average daily production from mechanized units, tons	1,890	Convey. 900 Scrapers 400	1,120
5. Thickness and dip of bed	54 inches - Level	40 inches	34 inches - Level
6. Number and hours of shift in mine	2 - 7 hr.	2 - 7 hr.	2 - 7 hr.
7. Number and hours of shift in tipple	2 - 7 hr.	1 - 7 hr.	1 - 7 hr.
8. Conveyors	12	Convey. 2 Scrapers 2	12
9. Conveyor shifts per day	28	4 4	24
10. Average production per conveyor per shift, tons	67	75 100	47
11. Average number of men per unit per shift	5.75	15.5 7.5	5.33
12. Man-shifts per day on mechanized units	161	92	128
13. Average production per man per day on mechanized units, tons	11.73	14.45 13.3	8.75
14. Total number of employees underground	179	113	148.5
15. Average production per day per man, underground, tons	10.56	11.5	7.54
16. Total number of employees, surface and underground	216	149	173
17. Average production per day per man employed, tons	8.75	8.7	7.47
18. Average production of coal per pound of explosives, tons	10.7	-	-
19. Average production of coal per prop, tons	5.0	-	-
20. Total power consumed per ton of coal, kw.-hr.	-	-	-
21. Size of mine car, tons	1.45	2.45	2.45
22. Estimated recovery, percent	82	80	95

1/ Includes both coal and brushing.

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Curves

The data of the various mines have been plotted as curves on figures 14, 15, 17, 18 and 19. They include, for comparative purposes, the information contained in Information Circulars 7178, 7067, and 7014, "Multiple-Shift Mechanical Mining in Some Bituminous-Coal Mines"6/;

Figure 14

As the thickness of the bed increases and approaches 8 feet in mines where pillars are not extracted, the tons per loading-machine shift increase at a more rapid rate than from 8 feet to 12 feet. When the machine approaches its loading capacity, the effect of the thickness of the bed becomes less apparent. The curve of pillar extraction follows the general trend of the curve of nonextraction, but the production per machine shift is lower for all bed thicknesses. The bed thickness in the mines recorded in curve A does not attain that recorded in cruve B. The loading machines of mines represented in curve B are approaching their rated capacity, but those of curve A are below capacity. Future investigations may include mines extracting pillars in bed thicknesses greater than 9 feet.

Figure 15

Curves A and B represent pillar extraction and nonpillar extraction, respectively. The curves have the same general characteristics. They vary chiefly in that more men are required per unit where pillar extraction is practiced.

The curves in figure 15 do not show occupations of the men comprising a loading-machine crew.

Figure 16

This figure gives the occupations of typical crews of pillar-extraction and nonpillar-extraction mines.

Figure 17

Curves A and B indicate that where pillars are extracted, the man-shifts per day required on mechanized units increase more rapidly as production increases than where pillars are not extracted. In addition, (see fig. 16), total man shifts per day increase more rapidly in pillar work than in nonpillar work. The number of nonproductive men in both instances remains approximately the same.

6/ Work cited.

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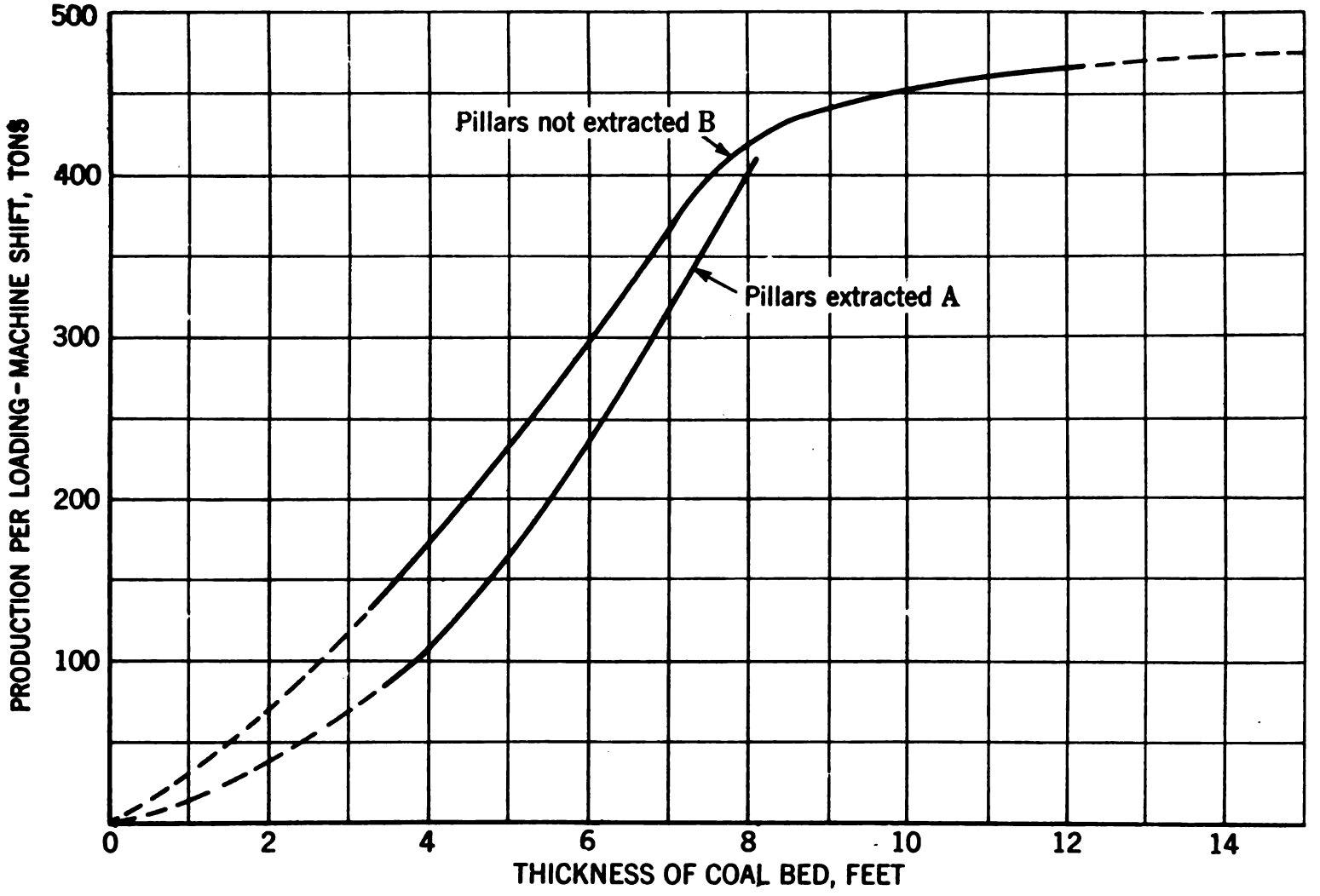

Figure 14.— Relation of thickness of bed to production per loading-machine shift (tons).

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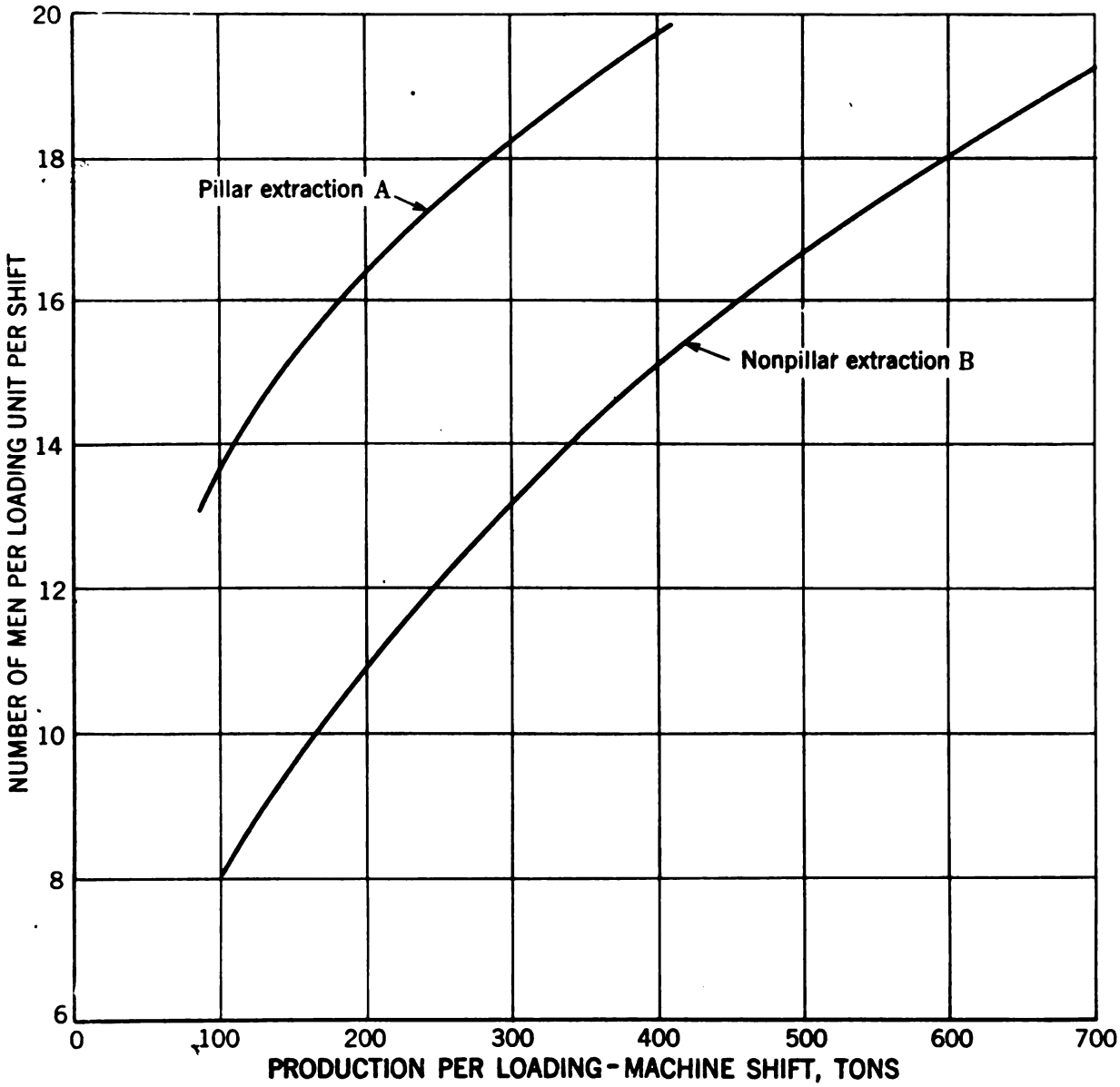

Figure 15.— Relation of number of men per loading-machine unit per shift to production per loading-machine shift (tons).

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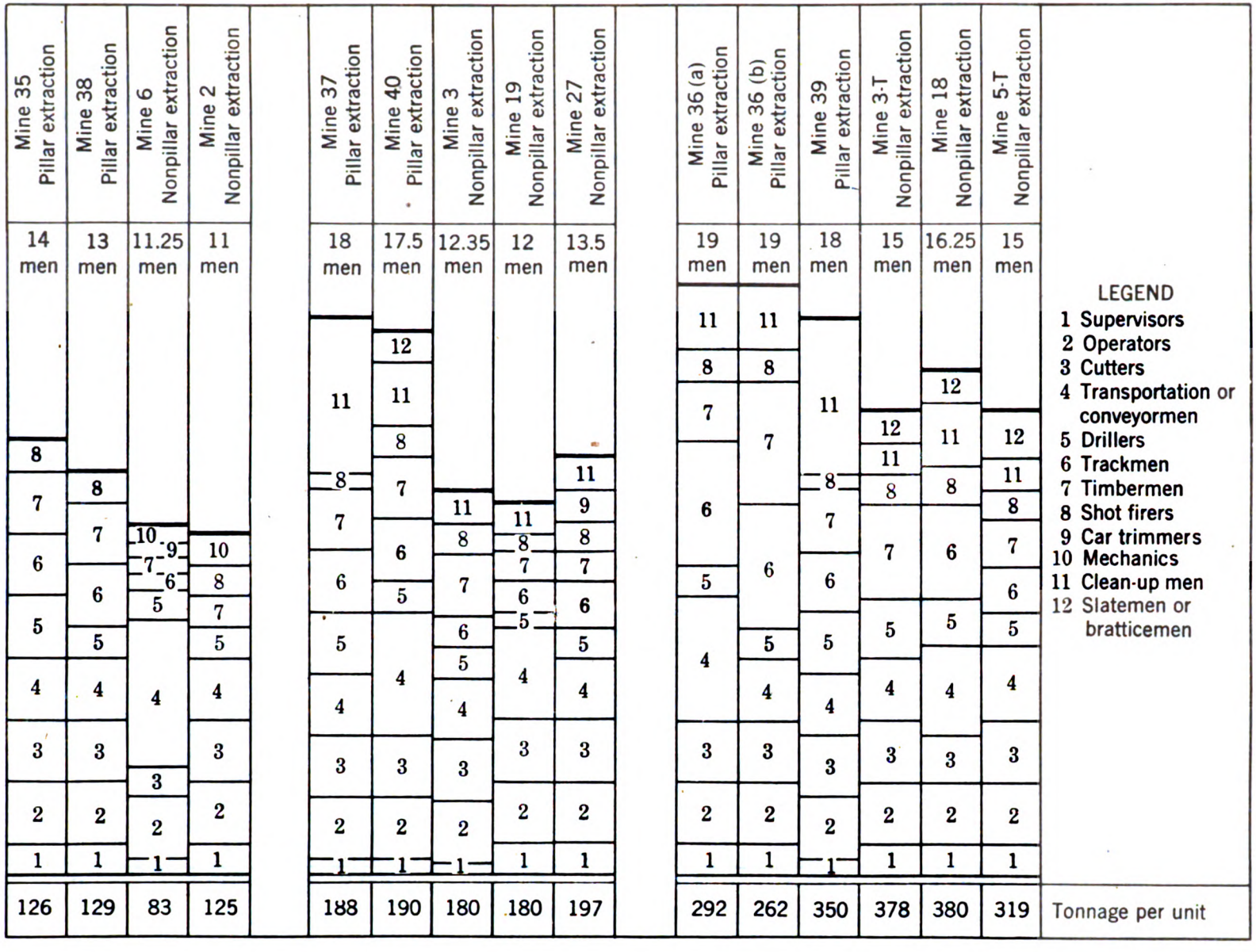

Figure 16.—Occupational distribution of loading crewmen.

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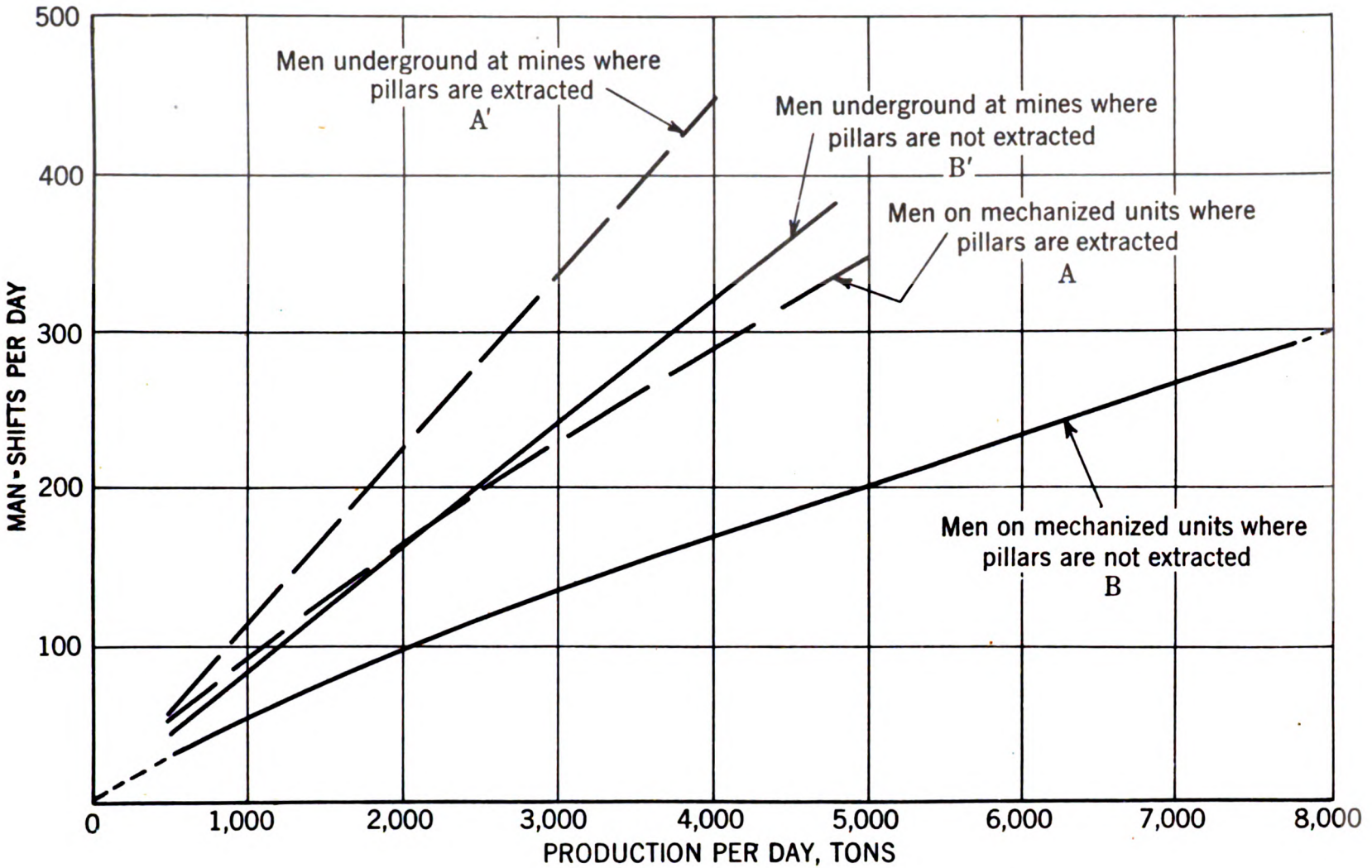

Figure 17.– Relation of man-shifts per day to production per day, mobile loading machine.

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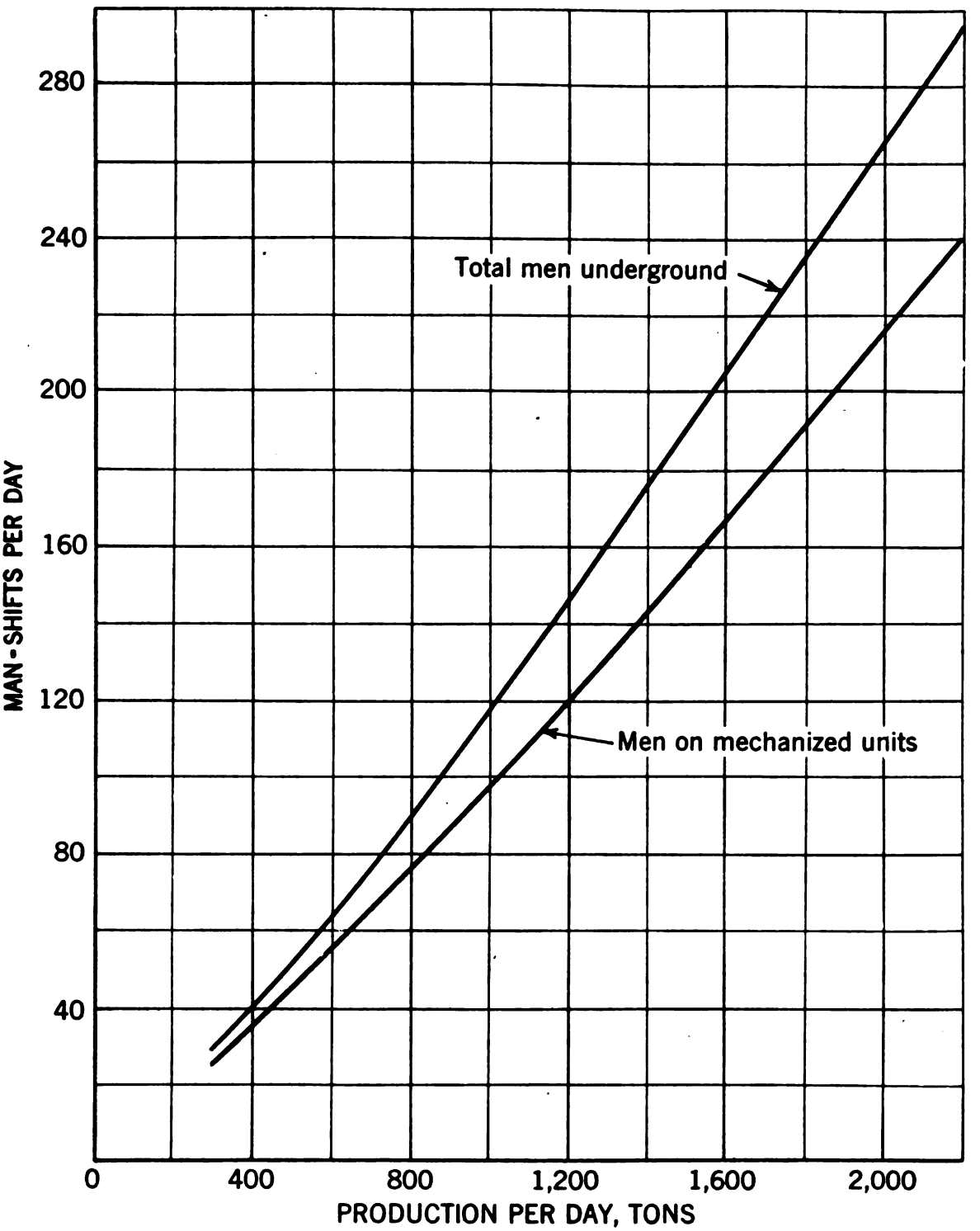

Figure 18.— Relation of man-shifts to production per day, conveyors.

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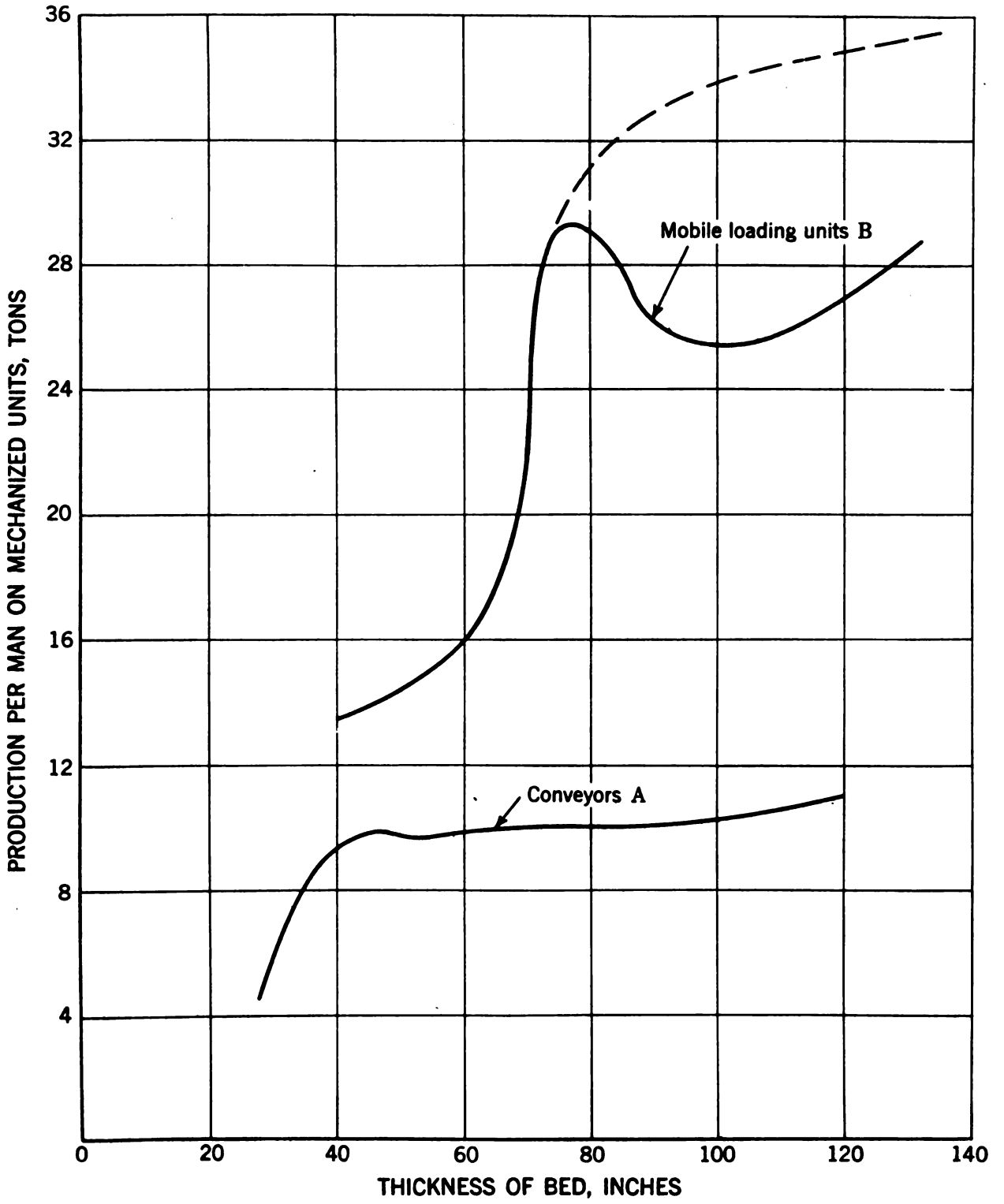

Figure 19.—Relation of bed thickness to production per man on mechanized unit (tons).

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Figure 18

This figure indicates that as the tonnage increases the number of men on mechanized units and underground increases at a uniform rate. The percentage of men at nonproductive work remains constant.

Figure 19

This figure indicates that for those mines reported in curve A the tons per man increase rapidly where the bed ranges from 28 to 45 inches in thickness. From that point tonnage remains virtually constant for greater thickness of bed. Use of conveyors in beds thicker than 50 inches does not increase loading efficiency. Curve B, mobile loading machines, indicates, by comparison with curve A, that where the bed is thicker than 50 inches it would be desirable to use mobile loading equipment, if physical conditions permit, rather than conveyors. The downward trend in curve B from 75 to 120 inches is caused by adverse conditions at the mines studied. Possibly future studies will tend to revise this curve to the approximate position of the dashed portion.

The output from loading equipment can be increased materially if all operations in the mining cycle are properly coordinated. Adequate number and preparation of working places, minimum tramming distances and car change are necessary to obtain maximum use of the loading equipment.

A mining company's chief asset is coal in the ground. Development of a mine to extract only a part of the bed is not only uneconomical but wasteful of a natural resource.

These studies are being made to determine methods of extraction that will yield maximum recovery with the greatest efficiency and safety.

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